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Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)

This is a DRAFT Version 4.2 Working Copy of this document.
It includes the published RTCA/DO-260A, plus Change 1 and Change 2 integrated into it.
It also has implemented into it those changes identified during Meeting #23 in Working Papers 1090-WP23-02 and1090-WP23-03R1, and those changes currently agreed to as acceptable changes in the Change Matrix of 1090-WP2X-03.
All changes to the original DO-260A are still highlighted in yellow.

RTCA DO-260B
Supercedes RTCA DO-260A, including Change 1 and Change 2

Prepared by: SC-186

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Foreword

This document was prepared by Special Committee 186 (SC-186) and approved by the RTCA Program Management Committee (PMC) on MM DD, YYYY.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

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- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunications Union and other appropriate international organizations can be based.

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1.0 PURPOSE AND SCOPE

1.1 Introduction

This document contains Minimum Operational Performance Standards (MOPS) for airborne equipment for Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service – Broadcast (TIS-B) utilizing 1090 MHz Mode-S Extended Squitter (1090ES). The supporting hardware can be incorporated within other on-board equipment, or alternatively, the ADS-B equipment may be a separate avionics unit.

Note: *Definitions of acronyms (e.g., MOPS, ADS-B, 1090ES) and of many other terms (e.g., "Extended Squitter") can be found in Appendix B of these MOPS. Throughout this document, the term "TIS-B" refers to the Fundamental TIS-B Service as defined in the TIS-B MASPS, RTCA/DO-286B, §1.4.1. The acronym "ADS-R" refers to the ADS-B Rebroadcast Service as defined in the TIS-B MASPS, RTCA/DO-286B, §1.4.1. The Fundamental TIS-B Service provides traffic information that is derived from ground surveillance (e.g., radar) systems. The ADS-B Rebroadcast Service provides the Rebroadcast on 1090 MHz of an ADS-B Message from an alternate data link using the same TYPE Codes and Message Formats as are defined for Downlink Format (DF) = 17 ADS-B Messages, with the exception of bits modified as identified in §2.2.18.*

Compliance with these standards by manufacturers, installers and users is recommended as one means of assuring that the equipment will satisfactorily perform its intended functions under conditions encountered in routine aeronautical operations. The regulatory application of these standards is the responsibility of appropriate government agencies. In the United States, the Federal Aviation Administration (FAA) publishes and maintains a Technical Standard Order (TSO C166) for ADS-B equipment to reference the requirements and bench test procedures in Section 2 of this document.

Since the equipment implementation includes a computer software package, RTCA DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, (EUROCAE ED-12B) is applicable. When determining the level of software requirements, as defined in RTCA DO-178B (EUROCAE ED-12B), the equipment manufacturer should consider the criticality appropriate for the installation certification, equipment failure analysis, and the fault monitoring being accomplished.

In addition, since the measured values of equipment performance characteristics may be a function of the measurement method, standard test conditions and methods of test are recommended in this document.

Section 1 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and, along with RTCA DO-242A, *Minimum Aviation System Performance Standards for ADS-B*, forms the basis for the standards stated in Sections 2 and 3.

Section 2 contains the minimum operational performance standards for the equipment. These standards define required performance under standard operating conditions and stressed physical environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

Section 3 describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational characteristics of the installed equipment, self test features, and controls.

Appendix A is *normative* whereas Appendices B through Q are *informative.* The following is a short description of each of the Appendices contained in this document:

- Appendix A defines the formats and coding for Extended Squitter ADS-B and TIS-B Messages, expanding upon the requirements of Section 2.2.

- Appendix B contains a list of acronyms and definition of terms used in this document.

- Appendix C discusses aircraft antenna performance characteristics and identifies references to obtain additional information on the subject.

- Appendix D defines a ground architecture that can support (1) surveillance for ATC using Extended Squitter ADS-B reports, and (2) TIS-B service.

- Appendix E contains air-to-air link budgets for each class of ADS-B equipment and summarizes the relationships between transmitter power, receiver sensitivity, and range under worst case and practical implementation conditions.

- Appendix F presents a traceability matrix to the ADS-B MASPS (RTCA DO-242A).

- Appendix G discusses transition issues for ADS-B avionics.

- Appendix H discusses ADS-B report assembly and provides additional guidance on the subject.

- Appendix I identifies and discusses examples of the enhanced reception techniques for Extended Squitter that have been shown to meet the enhanced reception performance requirements.

- Appendix J discusses determining the Navigation Accuracy Category for velocity (NAC_V) and describes the rationale for the values used in Table 2-25, “NAC_V Data.”

- Appendix K discusses and provides the results of an analysis that determined the affect of report assembly on velocity accuracy.

- Appendix L discusses and provides a table showing, by equipage class, the impact of radio frequency interference on Extended Squitter report integrity.

- Appendix M provides a description of techniques for extending the effective air-to-air range of 1090 MHz ADS-B Subsystems, and discusses the transmission power for Class A3 airborne installations.

- Appendix N defines the formats and coding for Extended Squitter ADS-B Messages that are broadcast by ADS-B Version Zero (0), RTCA DO-260 compliant 1090 MHz ADS-B Subsystems, and ADS-B Version One (1), RTCA DO-260A compliant 1090 MHz ADS-B Subsystems, and defines how the ADS-B Report Generation Function of Version Two (2) 1090 MHz ADS-B Receiving Subsystems is to utilize messages received from targets that are broadcasting with Version Zero (0) and Version One (1) Message formats.

- Appendix O provides specifics for possible future use of additional intent communications provided for in RTCA DO-242A as "Trajectory Change (TC) Reports."

- Appendix P presents the expected 1090 MHz Extended Squitter Performance in the LA2020 Scenario defined in the ADS-B MASPS, RTCA DO-242A, §3.3.4.

- Appendix Q presents a proposed format for a Runway Threshold On-Condition Message.

- Appendix R provides a calculation of 1090 MHz Extended Squitter broadcast rates for different operational scenarios to show that transmission rates achieved over a 60 second period meet the required average rate over 60 seconds, and that there is no need to implement a function to limit the total number of 1090 MHz Extended Squitters transmitted over a certain period of time.

- Appendix S specifies a method such that the Time Mark and UTC time can be synchronized at any Time within any Epoch on any sub-epoch.

- Appendix T provides a tutorial and gives explanations and derivations of the Compact Position Reporting (CPR) equations given in Appendix A. CPR encoding and decoding can be implemented without using any of the information in this appendix but, if a CPR implementation has problems, the information in this appendix may be helpful in resolving the issue.

1.2 System Overview

1.2.1 Definitions

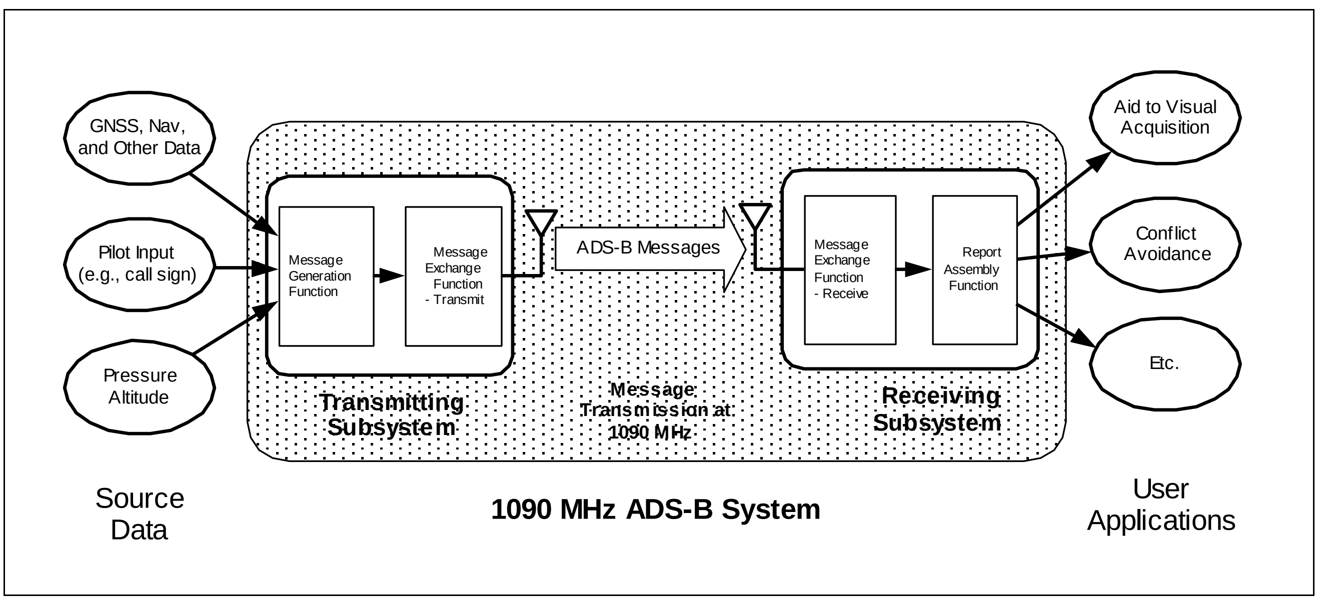
ADS-B (Automatic Dependent Surveillance – Broadcast) is a function for airborne or surface aircraft, or other surface vehicles operating within the airport surface movement area, that periodically transmits its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is *automatic* because no external stimulus is required; it is *dependent* because it relies on on-board navigation sources and on-board broadcast transmission systems to provide *surveillance* information to other users. The aircraft or vehicle originating the *broadcast* may or may not have knowledge of which users are receiving its broadcast; any user, either aircraft or ground-based, within range of this broadcast, may choose to receive and process the ADS-B surveillance information. ADS-B supports improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety such as conflict management.

TIS-B (Traffic Information Service – Broadcast) is a function in which transmitters on the ground provide aircraft with information about nearby aircraft. The TIS-B information is likely to come from ground-based surveillance sensors such as air traffic control radars or multilateration systems. However, TIS-B information broadcast on a particular radio data link might also be derived from the reception on the ground of ADS-B Messages that were transmitted on a different data link. For example, 1090 MHz TIS-B transmitters might broadcast information about nearby aircraft based on ground reception of ADS-B Messages on other data links.

For the purposes of this document, the term *Aircraft/Vehicle* (A/V) will refer to either 1) a machine or device capable of atmospheric flight, or 2) a vehicle on the airport surface movement area (i.e., runways and taxiways). For simplicity, the word *aircraft* is used to refer to aircraft and vehicles, where appropriate.

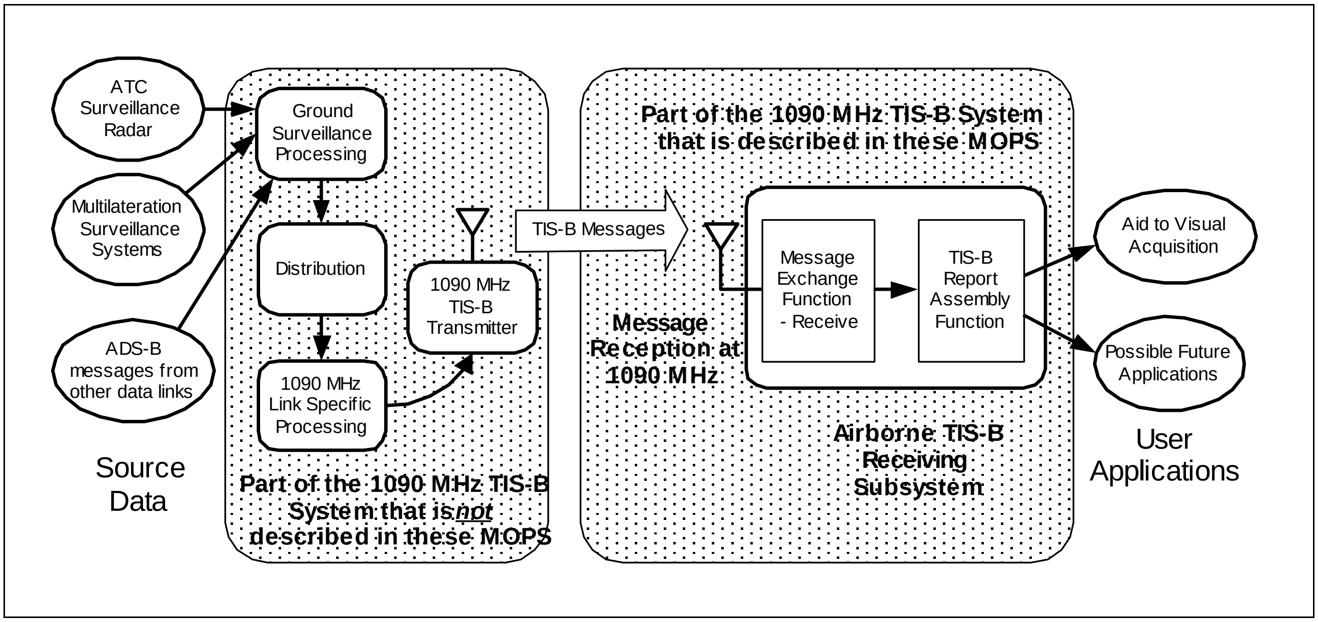
Figure 1-1 shows the extent of the 1090 MHz ADS-B system and its major components. This figure is adapted from the ADS-B MASPS, RTCA DO-242A.

As indicated in the figure, the ADS-B system includes the following components: message generation/transmission by the source A/V, propagation medium, and message reception/report assembling by the user. The ADS-B system does *not* include the sources of the data to be sent by the source subsystem on board the transmitting aircraft. Neither does it include the client applications, which use the information received by the ADS-B user subsystem on board the receiving aircraft. Some ADS-B participants may be able to transmit but not receive. In addition, some ground-based users may be able to receive but not to transmit.



<u>Figure 1-1:</u> The Scope of the 1090 MHz ADS-B System

Figure 1-2 shows the extent of the 1090 MHz TIS-B system and its major components. As indicated in Figure 1-2, only the 1090 MHz TIS-B Messages and airborne TIS-B Receiving Subsystem are described in these MOPS.



<u>Figure 1-2:</u> Scope of the 1090 MHz TIS-B System

1.2.2 1090 MHz ADS-B System

The "ADS-B Messages" transmitted on 1090 MHz are the Mode S Extended Squitters (Airborne Position squitter, Airborne Velocity squitter, Surface Position squitter, etc.) described in ICAO Doc 9871, and Appendix A of this document.

The source 1090 MHz Transmitting Subsystem may or may not be implemented in conjunction with a Mode S transponder.

The user 1090 MHz Receiving Subsystem may or may not be implemented in conjunction with a TCAS (Traffic Alert and Collision Avoidance System).

1.2.3 ADS-B Avionics Integrity

The integrity requirements for the total system to support ADS-B related applications are determined for a particular airborne architecture by conducting a functional hazard assessment and system safety assessment. For each application, the classification (typically expressed in terms of a category such as hazardous/minor, hazardous major, etc.) of unannunciated and unmitigated failure conditions of ADS-B avionics that cause out-of-tolerance error conditions will be derived from these assessments.

Guidance on the above assessments can be found in:

- SAE ARP4761 -- Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment;

- SAE ARP4754/ED79 -- Certification Considerations for Highly-Integrated or Complex Aircraft Systems;

- JAA AMJ 25.1309 -- Advisory Material Joint, System Design and Analysis;

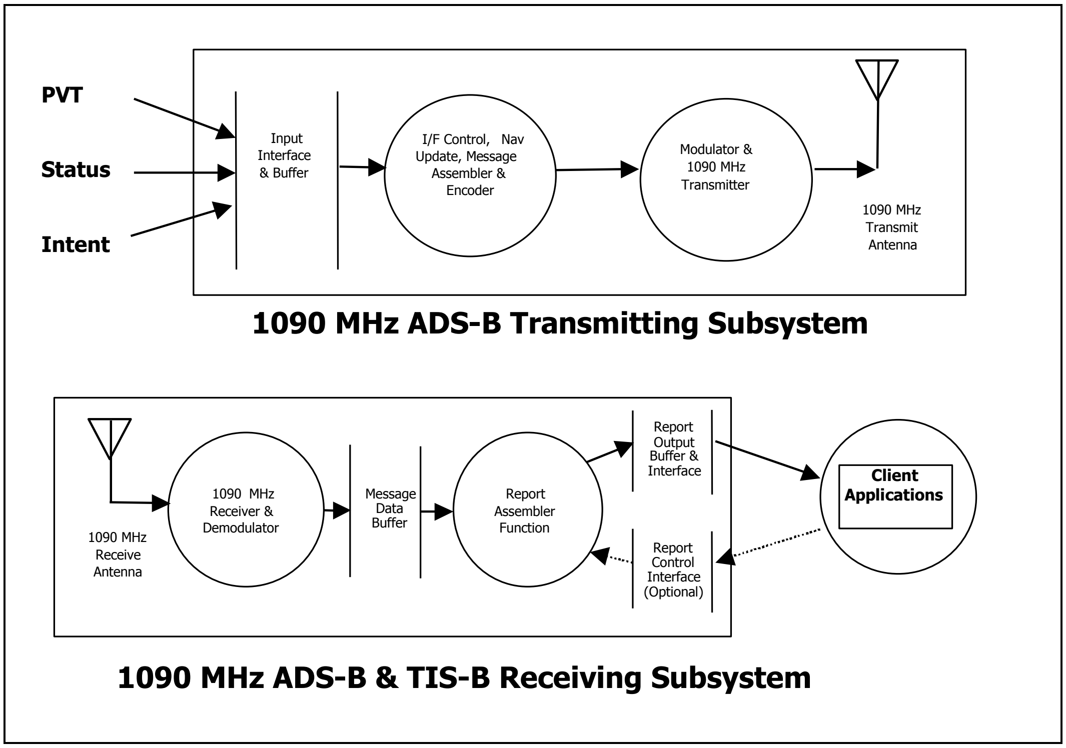
- FAA AC 23.1309-1C – Equipment, Systems, and Installations in Part 23 Airplanes;

- FAA AC 25.1309-1A -- Advisory Circular, System Design and Analysis.

Presuming that all 24 parity check bits (§2.2.3.2.1.7) are employed for error detection, the 1090 MHz ADS-B Message formats have been designed to support an undetected error rate of less than 1 undetected error per 10^7 ADS-B Messages.

1.2.4 1090 MHz ADS-B Subsystem Implementations

Figure 1-3 shows the 1090 MHz ADS-B Subsystems in more detail.



<u>Figure 1-3:</u> 1090 MHz ADS-B Subsystems.

1.2.4.1 Source 1090 MHz ADS-B Transmitting Subsystem

The source subsystem consists of a message generation function and a transmitting message exchange function. The 1090 MHz ADS-B Transmitting Subsystem takes PVT (Position, Velocity, Time), status, and intent inputs from other systems onboard the aircraft and transmits this information on the 1090 MHz frequency as Mode S Extended Squitter messages. The message generation function includes the input interface, message assembly, and encoding subfunctions. The message exchange function includes the radio equipment (modulator/transmitter) and 1090 MHz transmitting antenna subfunctions.

The ADS-B Transmitting Subsystem may be implemented either (a) using a Mode S secondary surveillance radar transponder, or (b) using Non-Transponder-Based 1090 MHz transmitting equipment.

1.2.4.1.1 Transponder-Based Subsystems

In a Mode S Transponder-Based Subsystem, the ADS-B Message generation function and the modulator and 1090 MHz transmitter are present in the Mode S transponder itself. The transmit antenna subfunction consists of the Mode S antenna(s) connected to that transponder.

1.2.4.1.2 Non-Transponder-Based Subsystems

Non-Transponder-Based ADS-B Subsystems might be installed in general aviation aircraft that have Mode A/C ATCRBS transponders rather than Mode S transponders. In such Non-Transponder-Based ADS-B Subsystems, the message generation function and the modulator and 1090 MHz transmitter will be housed together in the transmitting unit. The transmitting antenna subfunction may be separate from the transmitter unit or may also be incorporated in the unit.

Notes:

1. *The term "Non-Transponder-Based" within the context of DO-260B is not intended to preclude an avionics configuration with a 1090 MHz ADS-B capability integrated with a Mode A/C ATCRBS Transponder.*

2. *Installation of Non-Transponder-Based 1090 MHz ADS-B equipment in airplanes equipped with Mode-S transponders is prohibited. The transmission of squitters in addition to TCAS interrogation responses contributes unnecessary RF energy to the spectral environment. TCAS systems (in other airplanes) cannot take advantage of hybrid surveillance on the ADS-B data, since the non-transponder-based data cannot be validated by TCAS interrogation. ADS-B data is not directly available to ground interrogators as when it is read from transponder registers.*

1.2.4.2 1090 MHz ADS-B & TIS-B Receiving Subsystem

The 1090 MHz ADS-B and TIS-B Receiving Subsystem consists of a receiver message exchange function and a Report Assembly function. The 1090 MHz Receiving Subsystem takes ADS-B and TIS-B Mode S Extended Squitter messages and outputs information to other systems onboard the aircraft. The message exchange function includes the 1090 MHz receiving antenna and radio equipment (receiver/demodulator) subfunctions. The Report Assembly function includes the message decoding, report assembly, and output interface subfunctions. Several configurations of ADS-B Receiving Subsystems, which include the reception portion of the ADS-B Message Exchange Function and the ADS-B Report Assembly Function, are defined:

- Type 1 ADS-B and TIS-B Receiving Subsystems receive ADS-B and TIS-B Messages and produce application-specific subsets of ADS-B reports. Type 1 Receiving Subsystems are customized to the particular applications using ADS-B reports. Type 1 ADS-B Receiving Subsystems may additionally be controlled by an external entity to produce installation-defined subsets of the reports that those subsystems are capable of producing.
- Type 2 ADS-B and TIS-B Receiving Subsystems receive ADS-B and TIS-B Messages and are capable of producing complete ADS-B and TIS-B reports in accordance with the ADS-B equipment class. Type 2 Receiving Subsystems may be controlled by an external entity to produce installation-defined subsets of the reports that those subsystems are capable of producing.
- The ADS-B/TIS-B Message reception function may be physically partitioned into separate avionics from those that implement the ADS-B/TIS-B report assembly function.

1.2.4.2.1 Type 1 Report Assembly Function

In *Type 1* the Report Assembly Function may be closely coupled to the client application using the information provided by the ADS-B system. In this case, the ADS-B Report Assembly Function might reside together with the associated client application in one piece of equipment.

An advantage of a closely coupled assembler and application is that the Report Assembly function can be customized for the needs of the particular client application with which it is associated. If the client application does not require all of the State Vector elements listed in the ADS-B MASPS (RTCA DO-242A), then its associated Report Assembly function can customize the report by not providing the unneeded State Vector elements. Again, if the client application is only concerned with certain targets, then its Report Assembly function can optimize performance by filtering out targets that have no relevance to that application.

In a *Type 1* configuration, any further control of output reports (beyond the customization) would require a control interface by which the client application(s) can specify which and how reports are to be assembled or output.

The *Type 1* configuration has the advantage that it places only minimal processing requirements on the ADS-B Receiving Subsystem.

1.2.4.2.2 Type 2 Report Assembly

In *Type 2* the Report Assembly Function is of a general nature and is capable of supporting the needs of a variety of applications.

An advantage of *Type 2* is that it can support the needs of a variety of client applications, as it includes a generalized Report Assembly Function that can output reports that contain *all* the elements of the SV, MS, and OC reports as described in RTCA DO-242A.

In a *Type 2* configuration, any control of output reports would require a control interface by which the client application(s) can specify which and how reports are to be assembled or output.

1.2.4.3 Major Operating Characteristics

The 1090 MHz ADS-B/TIS-B System uses the Mode S Extended Squitter defined in the ICAO Annex 10, Volumes III and IV, to broadcast the Aircraft/Vehicle position, intent and other relevant information over the RF medium.

For ADS-B Messages, ICAO Doc 9871 provides the Mode S Transponder Register definitions as well as the 56-bit data formats required for the ADS-B Messages. Appendix A to this document specifies the formats contained in ICAO Doc 9871, plus those event-driven messages that are now defined. The transmission rate for each of the defined broadcast messages is defined in Appendix A and in the MOPS for *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode-S) Airborne Equipment* (RTCA DO-181D) (EUROCAE ED-73C).

TIS-B Messages have not yet been incorporated into the ICAO Annex 10 SARPs, nor into the Mode S Transponder MOPS (RTCA/DO-181D, EUROCAE ED-73C). TIS-B Messages are defined in §2.2.17 and §A.2 of this document.

The ADS-B Extended Squitters sent from a Mode S transponder use Downlink Format 17 (DF=17). Each squitter contains 112 bits, of which 56 bits contain the various navigation, intent, and other data comprising the ADS-B information. The other 56 bits include the 5-bit DF (Downlink Format) field, the 3-bit CA (Capability) field, the 24-bit AA (Announced Address) field, and the 24-bit PI (Parity/Interrogator ID) field.

Non-Transponder-Based ADS-B Transmitting Subsystems and TIS-B Transmitting equipment use DF=18. By using this format instead of DF=17, an ADS-B/TIS-B Receiving Subsystem will know that the message comes from equipment that cannot be interrogated.

The transmitter power is based on the classification of the ADS-B equipment. For example, ADS-B class A0 equipment may transmit at a lower power than class A3 equipment.

The operating range of the 1090 MHz Extended Squitter receiver is tailored to the classification of the equipment as well. Class A0 equipment may have a less sensitive receiver and thus support a comparatively short operating range. Class A3 equipment requires a more sensitive receiver, in order to receive ADS-B Messages from aircraft that are farther away.

The operation of the 1090 MHz ADS-B System must not have an adverse effect on other on-board systems. The ADS-B System may be used in conjunction with these other systems for increased accuracy and integrity of an aircraft's current navigational position and/or intent information.

1.2.5 Typical System Operation

A departing aircraft on the ground begins broadcasting its position and velocity via the 1090 MHz ADS-B System. This broadcast is received by other aircraft and the ground based receivers. The broadcasting aircraft also receives other aircraft broadcasts. The aircraft processes this information for use by applications that may involve Cockpit Display of Traffic Information (CDTI). As the aircraft taxis to its holding area, it monitors the movement of other aircraft on the surface as well as those in final approach. The aircraft on approach can also monitor the ground traffic and watch for a potential runway incursion and/or a blunder on a parallel approach area.

Once in the en route airspace, the aircraft broadcasts not only its position and velocity, but depending on the equipment classes, additional intent information. The aircraft performs various applications with the received broadcasts from other aircraft within range. These applications may include the use of CDTI, situational awareness, and de-confliction planning.

As the aircraft approaches its destination (terminal area), it monitors other proximate aircraft in order to maintain the desired separation for approach and landing.

1.2.6 ADS-B Message Content

The ADS-B Message refers to the transfer of data via 1090 MHz. An ADS-B Message is formatted data that conveys information used in the development of ADS-B reports. State Vector source data is provided by the platform dynamic navigation systems and sensors.

For the transponder case, the information for the state vector is contained in various registers. When broadcast, the contents of a register are inserted in the 56-bit message field of a 112-bit squitter transmission. The remaining 56 bits contain the aircraft address as well as required forward error correcting parity information. Appendix A to this document defines the contents of the various transponder registers.

1.2.7 ADS-B Report Content

The ADS-B Report refers to the restructuring of ADS-B Message data received from a 1090 MHz broadcast into various reports that can be used directly by other on-board applications. Four report types are defined for ADS-B outputs to applications. These report types are State Vector (SV), Mode Status (MS), Target State Report (TSR), and Air Referenced Velocity (ARV) Report.

1.2.7.1 State Vector Report

The State Vector report contains information about an aircraft or vehicle's current kinematic state as well as a measure of the accuracy of the State Vector. Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant. The State Vector data is the most dynamic of the three ADS-B reports; hence, the applications require frequent updates of the State Vector to meet the required accuracy for the operational dynamics of the typical flying aircraft or ground operations of aircraft and surface vehicles.

1.2.7.2 Mode Status Report

The Mode Status report contains current operational information about the transmitting participant. This information may include current call sign, address, and other information that may be needed at a lower update rate than the information in the State Vector. Specific requirements for a participant to transmit data for, and/or customize, this report type will vary according to the ADS-B equipage class of each participant.

1.2.7.3 Target State Report

The Target State Report contains information that will be broadcast (in Aircraft Target State and Status Messages, §2.2.3.2.7.1) when current Target State information is available. The Target State Report contains information that is required from only certain classes of ADS-B equipped aircraft. (See §2.2.8.3.1 for the format of the Target State Report.)

Note: *The ADS-B MASPS (RTCA DO-242A) describes a more general "On Condition" class of reports of which the Target State Report and the Air Referenced Velocity Report are the only instances that have so far been defined.*

1.2.7.4 Air Referenced Velocity Report

The Air Referenced Velocity Report (§2.2.8.3.2) contains velocity information that is required from only certain classes of ADS-B equipped aircraft. This report is only generated when Air Referenced Velocity information is being broadcast in the Airborne Velocity Message (§2.2.3.2.6).

Note: *Air Referenced Velocity Messages may be received from airborne aircraft that are also broadcasting messages containing ground referenced velocity information. ADS-B Receiving Subsystems conformant to these MOPS are required to receive and process ground referenced and Air Referenced Velocity Messages from the same aircraft and output the corresponding reports. Although not required in these MOPS, future versions of these MOPS will specify under what conditions both ground referenced and air referenced velocity would be transmitted. This is intended to provide compatibility with anticipated future requirements for the transmission of both types of velocity information.*

1.3 Operational Applications

The various equipment classes defined within this document are intended to provide a level of capability appropriate to a set of expected operational applications. Operational approval for specific applications should consider the total capability of all associated equipment installed in the aircraft. All airborne equipment will require a source of state vector data, such as a GNSS (GPS) receiver, an inertial/multisensor navigation system, or Flight Management System (FMS). Additional concepts, algorithms, procedures, and standards not defined within this document will also be required. This section describes several examples of applications that make use of ADS-B supplied information. Further examples may be found in RTCA DO-242A.

1.3.1 General Support for Surveillance

ADS-B is a cooperative system. All participating Aircraft and Vehicles (A/V) are required, at a minimum, to broadcast ADS-B Messages as specified in Section 2.2 of this document for each applicable equipment class. The broadcast of these messages provides the basic surveillance data necessary to support all other ADS-B applications.

1.3.2 Cockpit Display of Traffic Information (CDTI)

The CDTI provides the pilot with awareness of proximate traffic. A minimum system provides only the relative position and velocity vector of nearby traffic. Displays to support advanced applications may be required to supply additional information, pilot cues, or advanced alerting functions.

1.3.2.1 Aid to Visual Acquisition

An aid to visual acquisition application provides the pilot with information that supports visual acquisition as part of the normal see-and-avoid operations. Visual acquisition is applicable under visual meteorological conditions (VMC) regardless of whether the operations are being conducted under IFR or VFR.

1.3.2.2 Enhanced Traffic Situational Awareness

With the ability to display the full population of proximate aircraft, the CDTI may be used as an overall situational awareness tool. The CDTI is also seen as a key element to Free Flight operations. With mature Free Flight, and mutual controller/pilot agreement, separation responsibility may be delegated to the pilot. In this case, the ability to electronically "see and avoid" proximate aircraft becomes a necessary technology to enable the Free Flight concept. For example, the CDTI may be used for "Electronic VFR," with pilots applying "Rules of the Air" (as stated in ICAO Annex 2 to the Convention of International Aviation) to maintain safe separation.

1.3.3 Improvements to Aircraft-based Collision Avoidance

ADS-B is seen as a valuable technology to enhance operation of the Airborne Collision Avoidance System (ACAS). ADS-B data may be used to improve surveillance performance. It might also be used within the collision avoidance logic to reduce the number of unnecessary alerts.

1.3.4 Conflict Management and Airspace De-confliction

Conflict management and airspace de-confliction functions may be provided both by ground and aircraft automation systems. Aircraft conflict management functions will be used to support cooperative separation during the periods that separation responsibility has been delegated to the aircraft, such as in Free Flight. Ground conflict management functions will also be in place, both as a backup and as the primary tool to monitor aircraft for conflict detection. Airspace de-confliction based on the exchange of intent information will be used for strategic separation.

1.3.5 ATS Conformance Monitoring

ADS-B may be used to support and enhance ATS conformance monitoring, which is the process of ensuring that an aircraft maintains conformance to its agreed-to trajectory. The degree of deviation from the trajectory, or the conformance bounds, is based on factors such as the aircraft's navigation capability and the separation standards in place. Conformance monitoring occurs for all controlled aircraft or airspace, and applies to all operational airspace domains. In the case of protected airspace or Special Use Airspace (SUA), conformance monitoring is performed to ensure that an aircraft does not enter or leave a specific airspace. Conformance monitoring includes monitoring of simultaneous approaches to multiple runways, and surface operations.

1.3.5.1 Simultaneous Approaches

A specific example of conformance monitoring is the monitoring of simultaneous instrument approaches, a task that enables closer separation between aircraft on adjacent approach courses due to monitoring of each approach path by an ATS controller.

Parallel approaches that are not individually monitored require a stagger between aircraft on adjacent approaches, thus reducing arrival rates. Conformance monitoring of simultaneous approaches using a dedicated ATS controller for each approach stream allows simultaneous approaches to be flown. No stagger is required and the potential arrival rate can be 40 percent higher than for staggered approaches. Simultaneous approaches can be flown as close as 5000 ft (three runways) and 4300 ft (dual runways) with controllers using conventional sensors and displays, and as close as 3400 ft when controllers use PRM, which is a specialized sensor for simultaneous approaches. Simultaneous approaches may also be flown to converging runways, and in the future may be flown along curved or segmented courses that are tailored for local airport noise and arrival procedures. ADS-B may offer a viable alternative to expensive PRM technology to support simultaneous approaches, and may allow simultaneous approaches at airports that cannot currently justify the cost of a PRM or conventional equipment for simultaneous approach monitoring.

1.3.5.2 Incursion Monitoring

ADS-B information may be used to support incursion monitoring for both airborne and surface operations. Specific zones may be defined including:

- special use airspace,
- restricted airspace,
- hazardous weather locations,
- runways and taxiways,
- lighting control areas (areas where lighting is under ATS control)
- weight limited or wingspan limited areas, and
- other operational control zones such as noise sensitive areas.

Projected position information based on ADS-B State Vectors, when used in combination with zone incursion monitoring, can provide early warnings to ATS and the pilot.

1.3.6 Other Applications

Other applications for ADS-B may not be directly related to ground-based surveillance, CDTI, or a Traffic Situation Display (TSD), but still offer many users a direct economic or operational benefit. These should be developed and exploited as a means to encourage users to promptly and voluntarily equip with ADS-B systems. Some examples of these other applications are as follows:

- Improved Search and Rescue
- Enhanced Flight Following
- Lighting Control and Operation
- Aircraft Rescue and Fire Fighting (ARFF) Vehicle Operations
- General Aviation Operations Control

Further details on these and other potential ADS-B applications can be found in the ADS-B MASPS, RTCA DO-242A.

1.4 ADS-B Functions

The 1090 MHz ADS-B System can be viewed as being comprised of three major functions. These functions are the ADS-B Message Generation Function, the ADS-B Message Exchange Function, and the ADS-B Report Assembly Function.

The ADS-B Message Generation Function is responsible for assembling and structuring the data to be delivered via the 1090 MHz Extended Squitter. The ADS-B Message Exchange Function is then responsible for transferring this data at the required rate across the 1090 MHz frequency link. This function encompasses both the transmission and reception of the data. The ADS-B Report Assembly Function is responsible for structuring the received data into the appropriate ADS-B Reports for use by onboard applications.

1.4.1 ADS-B Message Generation Function

1.4.1.1 Avionics Input Bus

The information required for the various ADS-B reports are provided to the message generation function via avionics digital communication buses or a General Aviation interface. The majority of the information for air carrier installations may be obtained from avionics buses that contain ARINC 429 data labels for the required information.

1.4.1.2 Input Interface

For the transponder case, the Mode S transponder will provide the input interface for the required ADS-B Message data. This input may come directly from the source that supplies the data, i.e., an FMS unit, or from a data concentrator. The data concentrator would serve as the input for all source data and transfer this data to the transponder in the case of the 1090 MHz ADS-B System.

1.4.1.3 Message Assembly/Encoder

These subfunctions accept input data from other avionics sources and process this data into the appropriate format. For a Mode S Transponder-Based ADS-B system, this formatted data will then be inserted into DF=17 for transmission over the 1090 MHz frequency link. For a Non-Transponder-Based ADS-B system, the formatted data will be inserted into DF=18 for transmission.

1.4.2 ADS-B Message Exchange Function

The ADS-B Message Exchange Function provides for transmission and reception of the ADS-B Message over the 1090 MHz medium. The message exchange function also provides suitable integrity for ADS-B Messages.

1.4.2.1 Modulation/Transmission Subfunction

The modulation of the ADS-B Message transmission is Pulse Position Modulation (PPM) as specified in RTCA DO-181D (EUROCAE ED-73C). This modulation scheme is inherently resistant to ATCRBS interference. The information content of the transmission is further protected by parity check bits generated by a cyclic coding algorithm.

The transmitter subfunction generates the 1090 MHz carrier frequency and impresses the ADS-B information onto the carrier frequency. For Mode S Transponder-Based implementations, the transmitter requirements for transmission of the ADS-B data are defined in ICAO Annex 10, Volume IV, and also RTCA DO-181D (EUROCAE ED-73C). For Non-Transponder-Based implementations, transmitter requirements are contained in this document.

1.4.2.2 Transmit/Receive/Antenna Subfunction

The ADS-B transmit and receive subfunctions should be supported by one or two antennas depending upon aircraft installation for the operational unit. Two antennas are required if the transponder is coupled with an on-board TCAS, or if the aircraft's weight or maximum airspeed is such that diversity is specified in ICAO Annex 10. The diversity installation should be such that one antenna is mounted on the top of the fuselage and the other on the underside. The antennas should be capable of receiving and transmitting the 1090 MHz frequency (D-Band).

For best coverage in the yaw plane, the ADS-B antennas should be designed to radiate and receive vertically polarized RF signals. The antennas should be designed such that the ADS-B System is capable of performing its intended functions. This includes all azimuth headings with respect to any radial direction from another ADS-B System receiver when in the transmit mode or to another ADS-B transmitter when in the receive mode.

Note: *For the transponder case, the antenna should also be capable of receiving the 1030 MHz frequency for use in the ATCRBS/Mode S environment.*

These subfunctions should be designed to receive the RF signals of airborne aircraft and Aircraft/Vehicles operating on the ground. Detailed requirements are given in Section 2.2 to establish a receive antenna suitable for the ADS-B function.

1.4.2.3 Receiver/Demodulator Subfunction

The ADS-B Message is received over the 1090 MHz frequency link, demodulated, and output to the Report Assembly function. The minimum trigger level (MTL) defines the minimum input power that results in reliable reception and is suitable for receiving the information necessary for an ADS-B report. The MTL may vary to effectively increase or reduce the range depending on the phase of flight. Dynamic MTL may be used to reject low level multipath and interference.

1.4.3 ADS-B Report Assembly Function

1.4.3.1 Decoder/Report Assembly

Once the ADS-B Message is received, the decoder and message assembly subfunctions provide all control, decoding, and formatting functions needed to convert the received messages into the appropriate formatted reports for use by client applications. These subfunctions may be performed in the 1090 MHz receiver unit itself or an external processing unit that interfaces to the receiver.

Since the ADS-B information will be transmitted in multiple messages, the message assembler may require the use of a tracker. The message assembly and tracking processor will structure the received messages into the appropriate output data reports. It also verifies that the output data reports are valid prior to delivery to the Output Interface subfunction.

1.4.3.2 Output Interface

The Report Assembly function will output information through the interface for use by client applications that may involve CDTI. The Report Assembly/output processor serves as the output control for ADS-B Message data and transfers this data to client applications.

1.4.3.3 Avionics Output Bus

The information required for the various client applications is provided by the Report Assembly function, via avionics digital communication buses or a General Aviation interface. The majority of the information for air carrier installations may be delivered with avionics buses that contain ARINC 429 data labels for the required information.

1.5 Operational Goals

The aviation industry has articulated the goal of leveraging ADS-B equipage, in conjunction with technologies/services such as GPS, Traffic Information Service—Broadcast (TIS-B), Flight Information Service—Broadcast (FIS-B), and two-way digital aeronautical data link, to support operational enhancements leading toward free flight [Joint Government/Industry Plan for Free Flight Operational Enhancements, August 1998, RTCA Flight Select Committee]. A number of the operational applications cited in Section 1.3 are involved in this effort, most notably to support Improved Terminal Operations in Low Visibility Conditions, Enhanced Visual Operations and Situational Awareness, Enhanced Operations for En Route and Oceanic Air-to-Air, Improved Surface/Approach Operations, a Surface and Airport Vicinity Display for the Controller, Use of ADS-B in Non-Radar Airspace, and Use of ADS-B to Enhance Radar and Automation Performance. ADS-B is a technical linchpin for supporting seven of the ten identified operational enhancements.

Operational scenarios have been developed for each of the above Free Flight Enhancements, and more detailed operational concepts are being completed. The detailed operational concepts are being used to develop a comprehensive roadmap for surveillance airborne and ground system development and interoperability.

1.6 Assumptions and Rationale

Throughput requirements for ADS-B Message reception have been developed so that the equipment can process the maximum number of messages that can be supplied on the 1090 MHz medium. The ADS-B Report Assembly function, whether or not physically collocated with the ADS-B Message reception function, will similarly be required to be capable of accepting this number of messages as output by the ADS-B receiver function.

1.7 Test Procedures

The test procedures specified in Sections 2.4 and 3 are intended to be used as recommended means of demonstrating compliance with the minimum acceptable performance parameters specified herein. Although specific test procedures are cited, it is recognized that other methods may be suitable. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

1.7.1 Environmental Tests

Environmental tests are specified in Section 2.3. These tests, like bench tests, are performed at the equipment level. The procedures and their associated requirements provide a laboratory means of determining the electrical and mechanical performance of the equipment under conditions expected to be encountered in actual aeronautical operations. Test results may be used by equipment manufacturers as design guidance, in preparation of installation instructions and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.7.2 Qualification Tests

The test procedures specified in Section 2.4 provide a means to demonstrate equipment performance in a simulated environment. Test results may be used as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design and manufacture.

Test procedures contained in Section 2.4 apply to the minimum system requirements in accordance with the minimum performance parameters specified in these MOPS.

1.7.3 Installed Tests

The installed test procedures and their associated limit requirements are in Section 3. Although bench and environmental test procedures are not a part of installed tests, their successful completion is normally a precondition to the completion of the installed tests. Installed tests are normally performed on the ground and in flight.

The test results may be used to demonstrate equipment functional performance in the environment in which it is intended to operate and with the minimum service to be provided.

1.8 MASPS Compliance

A detailed listing of compliance with the ADS-B MASPS is contained in Appendix F.

1.9 Definition of Key Terms

Appendix B provides a glossary of the terms used in this document. This section expands upon the definitions of key terms in order to increase document clarity and establish a common foundation of terminology.

ADS-B Broadcast and Receive Equipment - Equipment that can transmit and receive ADS-B Messages. Defined as Class A equipment.

ADS-B Broadcast Only Equipment - Equipment that can transmit but not receive ADS-B Messages. Defined as Class B equipment. Includes Transponder-Based equipment that is capable of receiving 1030 MHz SSR interrogations.

ADS-B Message - A modulated packet of formatted data that conveys information used in the development of ADS-B reports.

ADS-B Receiver or 1090 MHz Receiver - An ADS-B Receiving Subsystem that is not part of a TCAS 1090 MHz receiver.

ADS-B Report - Specific Information provided by the ADS-B user participant subsystem to external applications. Reports contain identification, state vector, and status/intent information. Elements of the ADS-B Report that are used and the frequency with which they must be updated will vary by application. The portions of an ADS-B Report that are provided will vary by the capabilities of the transmitting participant.

Non-Transponder-Based Implementation - An ADS-B Transmitting Subsystem that is not part of a Mode S transponder.

TCAS Implementation – An ADS-B Receiving Subsystem implemented as part of a TCAS receiver.

Transponder-Based Implementation - An ADS-B Transmitting Subsystem implemented as part of, or added capability to, a Mode S transponder.

2.0 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.1.1 Airworthiness

In the design and manufacture of the equipment, the manufacturer **shall** provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment **shall** perform its intended function(s), as defined by the manufacturer, and its proper use **shall** not create a hazard to other users of the National Airspace System.

Note: *A manufacturer defines the functions to be included in a particular piece of equipment, and these functions will then comply with the applicable MOPS.*

2.1.3 Federal Communications Commission Rules

All equipment **shall** comply with the applicable rules of the Federal Communications Commission.

2.1.4 Fire Protection

All materials **shall** be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note: *One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.*

2.1.5 Operation of Controls

The equipment **shall** be designed so that controls intended for use in flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the reliability of the equipment or operation of the aircraft. If the optional Extended Squitter inhibit capability per §2.1.5.1 is included, a means **shall** be provided to annunciate this status to the pilot.

2.1.5.1 Optional Extended Squiter Inhibit

There is no requirement to include a control to allow pilot entry to inhibit the transmission of Extended Squitters. However, if Extended Squitter capability is supported as per RTCA DO-181D, §2.2.23 (EUROCAE ED-73C, §3.28), *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*, dated October 2, 2008, the requirements of RTCA DO-181D, §2.2 (EUROCAE ED-73C, §3.0) apply, including the loading and servicing of the Extended Squitter related ground initiated Comm-B Registers identified in RTCA DO-181D, §2.2.23 (EUROCAE ED-73C, §3.28), but with the following exceptions:

1. The RF transmission of Extended Squitter messages is disabled when Extended Squitters are inhibited by pilot entry, consistent with the power limit requirements of RTCA DO-181D, §2.2.3.3 (EUROCAE ED-73C, §3.3.4).

2. The transponder is not considered failed, as per RTCA DO-181D, §2.2.10.2 (EUROCAE ED-73C, §3.14.2), when Extended Squitters are not transmitted as a result of Extended Squitter being inhibited by pilot entry.

3. For the purposes of determining whether to transmit the acquisition squitter as per RTCA DO-181D, §2.2.18.2.6 (EUROCAE ED-73C, §3.22.2.6), acquisition squitters are always transmitted when Extended Squitters are inhibited by pilot entry.

2.1.6 Accessibility of Controls

Controls that do not require adjustment during flight **shall** not be readily accessible to flight personnel.

2.1.7 Equipment Interfaces

The interfaces with other aircraft equipment **shall** be designed such that, properly installed with adequately designed other equipment, normal or abnormal ADS-B equipment operation **shall** not adversely affect the operation of other equipment nor **shall** normal or abnormal operation of other equipment adversely affect the ADS-B equipment except as specifically allowed.

2.1.8 Effects of Test

The equipment **shall** be designed so that the application of specified test procedures **shall** not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

2.1.9 Design Assurance

The equipment **shall** be designed to the appropriate design assurance level(s) based on the intended application of the equipment and aircraft class in which it is to be installed. The appropriate design assurance level(s) are determined by an analysis of the failure modes of the equipment and a categorization of the effects of the failure on the operation of the aircraft. For the purpose of this analysis, a failure is defined as either a loss of function or the output of misleading information. Additional guidance is contained in Advisory Circulars AC 23.1309-1C and AC 25.1309-1A.

Software included as part of the equipment **shall** be developed in compliance with the appropriate software level as specified in RTCA DO-178B, *Software Considerations in Airborne Systems and Equipment Certification* (EUROCAE ED-12B).

2.1.10 Integration and Interoperability with a Mode S Transponder

If the ADS-B equipment is integrated into a Mode S transponder, the transponder functions **shall** meet the appropriate requirements specified in the *MOPS for Air Traffic Control*

Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment (RTCA DO-181D) (EUROCAE ED-73C).

If the ADS-B equipment is designed as a stand-alone system, it **shall** be interoperable within the Mode S environment.

2.1.11 Equipage Class Definitions

ADS-B equipment is categorized into aircraft system equipage classes as defined in Table 3-1 of RTCA DO-242A (ADS-B MASPS). For 1090 MHz ADS-B equipment, those definitions are repeated in these MOPS in Table 2-1.

The Class "A" Aircraft/Vehicle Classes (A0, A1, A2, and A3) are as defined in RTCA DO-242A. Class A equipment is interactive, transmit and receive equipment, used for both aircraft and vehicles. The ADS-B MASPS "A1" equipment has been further divided into two classes, based on antenna diversity. For A1 installations using a single antenna, the "A1 Single" class is created, and abbreviated throughout this document as "A1S." A1 installations with diversity antennas are abbreviated throughout this document as "A1." The only equipment difference between classes A1 and A1S is antenna diversity.

The ADS-B MASPS "B0" class (broadcast-only aircraft) is defined as having transmitter characteristics and payload capability identical to the 1090 MHz A0 interactive aircraft class. The ADS-B MASPS "B1" class (broadcast-only aircraft) is defined as having transmitter characteristics and payload capability identical to the 1090 MHz A1 interactive aircraft class. The ADS-B MASPS "B1" equipment has been further divided into two classes, based on antenna diversity. For B1 installations using a single antenna, the "B1 Single" class is created, and abbreviated throughout this document as "B1S." B1 installations with diversity antennas are abbreviated throughout this document as "B1." The only equipment difference between classes B1 and B1S is antenna diversity.

The characteristics of the 1090 MHz "B2" class (broadcast-only ground vehicle) are defined in Table 2-1.

The characteristics of the 1090 MHz "B3" class (broadcast-only fixed or moveable obstacle) are defined in Table 2-1. The payload capability supports the surface position, height of highest point, and identification (including Emitter Category) of the obstacle, so that both State Vector and Mode Status reports must be supported. Moveable obstacles require a position source. A moveable obstacle is one that can change its position, but only slowly, such that its horizontal velocity may be ignored.

Requirements for Class 'C' ground-based receive-only equipment are not addressed in this document.

2.1.12 Equipage Class Categories

ADS-B equipment is categorized into aircraft system equipage classes as specified in the ADS-B MASPS (RTCA DO-242A) and as summarized in Table 2-1. These class categories are based on both the aircraft's on-board transmitter and receiver capabilities. The system classes are then broken down into subsystem equipment classes that are based on the individual unit specifications (refer to §2.1.12.1 and §2.1.12.2). Table 2-2 lists the different types of ADS-B Messages in the 1090 MHz ADS-B system.

Table 2-1: ADS-B Aircraft System Classes

Class	Subsystem	Features
Interactive Aircraft/Vehicle Participant Systems (Class A)		
A0	Minimum Interactive Aircraft/Vehicle	Lower transmit power and less sensitive receive than Class A1.
A1S/A1	Basic Interactive Aircraft	Standard transmit power and more sensitive receiver. Class A1 implements Antenna Diversity (Note)
A2	Enhanced Interactive Aircraft	Standard transmit power and more sensitive receiver. Interface with avionics source required for aircraft trajectory intent data. Antenna Diversity (Note)
A3	Extended Interactive Aircraft	More sensitive receiver. Interface with avionics source required for aircraft trajectory intent data. Antenna Diversity (Note)
Broadcast-Only Participant Systems (Class B)		
B0	Aircraft Broadcast Only	Transmit power may be matched to coverage needs. Nav data input required.
B1S/B1	Aircraft Broadcast Only	Transmit power may be matched to coverage needs. Nav data input required. Class B1 implements Antenna Diversity (Note)
B2	Ground Vehicle Broadcast Only	Transmit power matched to surface coverage needs. High accuracy Nav data input required.
B3	Fixed Obstacle	Fixed coordinates. No Nav data input required. Collocation with obstacle not required with appropriate broadcast coverage.
Ground Receive Systems (Class C)		
C1	ATS En Route and Terminal Area Operations	Requires ATS certification and interface to ATS sensor fusion system.
C2	ATS Parallel Runway and Surface Operation	Requires ATS certification and interface to ATS sensor fusion system.
C3	Flight Following Surveillance	Does not require ATS interface. Certification requirements determined by user application.

***Note:*.** *See §3.3.1 for Antenna Diversity.*

Table 2-2: ADS-B Message To Requirement Cross-Reference Table

Message	Reference Section
AIRBORNE POSITION	§2.2.3.2.3
SURFACE POSITION	§2.2.3.2.4
AIRCRAFT IDENTIFICATION and CATEGORY	§2.2.3.2.5
AIRBORNE VELOCITY (Subtypes 1, 2, 3, & 4)	§2.2.3.2.6.1- §2.2.3.2.6.4
TARGET STATE AND STATUS (Subtype=1)	§2.2.3.2.7.1
AIRCRAFT OPERATIONAL STATUS	§2.2.3.2.7.2
TEST MESSAGE (Subtype 0)	§2.2.3.2.7.3
SURFACE SYSTEM STATUS	§2.2.3.2.7.4
RESERVED MESSAGE TYPES	§2.2.3.2.7.5 - §2.2.3.2.7.6
RESERVED FOR TRAJECTORY CHANGE MESSAGE	§2.2.3.2.7.7
EXTENDED SQUITTER AIRCRAFT STATUS (Subtypes 1 and 2)	§2.2.3.2.7.8
RESERVED MESSAGE TYPE	§2.2.3.2.7.9

2.1.12.1 Transmitting Subsystem

An ADS-B Transmitting Subsystem is classified according to the unit's range capability and the set of parameters that it is capable of transmitting. Manufacturers should take into consideration the equipment's intended operation when determining the minimum set of messages that the unit will be required to transmit (refer to Table 2-3 and Table 2-4).

Table 2-3: ADS-B Class A Transmitter Equipment To Message Coverage

<table>
<tr><th>Transmitter Class</th><th>Minimum Transmit Power (at Antenna Port)</th><th>MASPS Requirement (RTCA DO-242A)</th><th>Minimum Message Capability Required (From Table 2-2)</th></tr>
<tr><td rowspan="2">A0
(Minimum)</td><td rowspan="2">70 W</td><td>SV
MS</td><td>Airborne Position
A/C Identification & Category
Airborne Velocity
A/C Operational Status
Extended Squitter A/C Status</td></tr>
<tr><td>SV
MS</td><td>Surface Position
A/C Identification & Category
A/C Operational Status
Extended Squitter A/C Status</td></tr>
<tr><td rowspan="2">A1S/A1
(Basic)</td><td rowspan="2">125 W</td><td>SV
MS</td><td>Airborne Position
A/C Identification & Category
Airborne Velocity
A/C Operational Status
Extended Squitter A/C Status</td></tr>
<tr><td>SV
MS</td><td>Surface Position
A/C Identification & Category
A/C Operational Status
Extended Squitter A/C Status</td></tr>
<tr><td rowspan="2">A2
(Enhanced)</td><td rowspan="2">125 W</td><td>SV
MS
TS
TC+0</td><td>Airborne Position
A/C Identification & Category
Airborne Velocity
A/C Operational Status
Extended Squitter A/C Status
Target State and Status
Reserved for TC Message</td></tr>
<tr><td>SV
MS</td><td>Surface Position
A/C Identification & Category
A/C Operational Status
Extended Squitter A/C Status</td></tr>
<tr><td rowspan="2">A3
(Extended)</td><td rowspan="2">200 W</td><td>SV
MS
TS
TC+n</td><td>Airborne Position
A/C Identification & Category
Airborne Velocity
A/C Operational Status
Extended Squitter A/C Status
Target State and Status
Reserved for TC Message</td></tr>
<tr><td>SV
MS</td><td>Surface Position
A/C Identification & Category
A/C Operational Status
Extended Squitter A/C Status</td></tr>
</table>

Table 2-4: ADS-B Class B Transmitter Equipment To Message Coverage

Transmitter Class	Minimum Transmit Power (at Antenna Port)	MASPS Requirement (RTCA DO-242A)	Minimum Message Capability Required (From Table 2-2)
B0 (Aircraft)	70 W [1]	SV MS	Airborne Position A/C Identification and Category Airborne Velocity A/C Operational Status Extended Squitter A/C Status
			Surface Position A/C Identification and Category A/C Operational Status Extended Squitter A/C Status
B1S/B1 (Aircraft)	125 W [1]	SV MS	Airborne Position A/C Identification and Category Airborne Velocity A/C Operational Status Extended Squitter A/C Status
			Surface Position A/C Identification and Category A/C Operational Status Extended Squitter A/C Status
B2 (Ground Vehicle)	70 W [1]	SV MS	Surface Position A/C Identification and Category A/C Operational Status
B3 (Fixed Obstacle)	70 W [1]	SV MS	Airborne Position A/C Identification and Category A/C Operational Status

[1] – May be increased based upon application specific needs.

Notes: *(Table 2-3 and Table 2-4):*

1. *SV = State Vector, MS = Mode Status, TS = Target State, TC = Trajectory Change*
2. *SV elements are specified in Table 2-81.*
3. *MS elements are specified in Table 2-88.*

4. *On-Condition reports is a category that includes multiple report types. Each specific On-Condition report type includes the following elements:*

- *Target State Report (see Table 2-94)*
    - *Time of Applicability*
    - *Horiztonal Short Term Intent*
    - *Vertical Short Term Intent*
- *Air Referenced Velocity Report (see Table 2-96)*
    - *Address (the ICAO 24-bit Address)*
    - *Time of Applicability*
    - *Airspeed*
    - *Heading*
- *Reserved for Trajectory Change Reports*

2.1.12.2 Receiving Subsystem

An ADS-B Receiving Subsystem is classified by the sensitivity and the set of parameters that it is capable of formatting into reports. Manufacturers should take into consideration the equipment's intended operation when determining the minimum set of reports that the unit will be required to develop (refer to Table 2-5, Table 2-6 and Table 2-6A).

Table 2-5: ADS-B Class A Receiver Equipment To Report Coverage

Receiver Class	Minimum Trigger Threshold Level (MTL)	Reception Technique	MASPS Requirement [RTCA DO-242A Table 3-3(a)]	Minimum Report Required
A0 (Minimum)	-72 dBm	Standard	SV MS	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2)
A1S/A1 (Basic)	-79 dBm	Enhanced (§2.2.4.4)	SV MS ARV	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Air Referenced Velocity Report (ARV) (§2.2.8.3.2)
A2 (Enhanced)	-79 dBm	Enhanced (§2.2.4.4)	SV MS TS ARV TC+0	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Reports
A3 (Extended)	-84 dBm	Enhanced (§2.2.4.4)	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Reports

Table 2-6: ADS-B Class C Receiver Equipment To Report Coverage

Receiver Class	Minimum Trigger Threshold Level (MTL)	Operation	MASPS Requirement [RTCA DO-242A Table 3-3(b)]	Minimum Report Required
C1 (ATS En Route and Terminal)	Not Specified in these MOPS	Supports Cooperative ATC Surveillance Services	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Report(s)
C2 (Approach and Surface)	Not Specified in these MOPS	Supports Cooperative ATC Surveillance Services	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Report(s)
C3 (Flight Following)	Not Specified in these MOPS	Supports Private User Operations Planning and Flight Following	SV MS	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2)

Note: *(Table 2-5 and Table 2-6):*

SV = State Vector, MS = Mode Status, OC = On-Condition TS = Target State, ARV = Air Referenced Velocity, TC = Trajectory Change

Table 2-6A: ADS-B Class R Receive-Only Equipment To Report Coverage

Receiver Class	Minimum Trigger Threshold Level (MTL)	Reception Technique	MASPS Requirement [RTCA DO-242A Table 3-3(a)]	Minimum Report Required
R0 (Minimum)	-72 dBm	Standard	SV MS	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2)
R1S/R1 (Basic)	-79 dBm	Enhanced (§2.2.4.4)	SV MS ARV	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Air Referenced Velocity Report (ARV) (§2.2.8.3.2)
R2 (Enhanced)	-79 dBm	Enhanced (§2.2.4.4)	SV MS TS ARV TC+0	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Reports
R3 (Extended)	-84 dBm	Enhanced (§2.2.4.4)	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Reports

2.2 Minimum Performance Standards - Standard Conditions and Signals

2.2.1 Definition of Standard Conditions

Unless otherwise noted, the signal levels specified for transmitting devices in this subsection exist at the antenna end of a transmitter to antenna transmission line of loss equal to the maximum for which the transmitting function is designed.

Likewise, unless otherwise noted, the signal levels specified for receiving devices in this subsection exist at the antenna end of an antenna to receiver transmission line of loss equal to the maximum for which the receiving function is designed.

Note: *Transmitting or receiving equipment may be installed with less than the designed maximum transmission line loss. Nevertheless, the standard conditions of this document are based on the maximum design value. Insertion losses internal to the antenna should be included as part of the net antenna gain.*

2.2.2 ADS-B Transmitter Characteristics

2.2.2.1 Mode S Transponder-Based Transmitters

a. Transmitters for Class A1, A1S, B1 and B1S systems **shall** be based on Mode S transponders with RF Peak Output Power levels as specified in §2.2.2.1.1.2. Transmitters for Class A2, A3 systems **shall** be based on Mode S transponders with RF Peak Output Power levels as specified in §2.2.2.1.1.3, or §2.2.2.1.1.4, respectively, for the class of equipment.

b. Transmitters for Class A0 and Class B0 systems may also be based on Mode S transponders with RF Peak Output Power levels as specified in §2.2.2.2.10.

c. If the ADS-B transmitter is based on Mode S transponders, then for transponder functions it **shall** comply with RTCA DO-181D (EUROCAE ED-73C) for each class of transponder specified in the latest version of FAA TSO-C112. For ADS-B functions, it **shall** comply with the latest version of FAA TSO-C166.

2.2.2.1.1 RF Peak Output Power (minimum)

The minimum RF peak output power of each pulse of each transmitted message at the terminals of the antenna **shall** be as provided in the following subparagraphs for each class of equipment addressed.

2.2.2.1.1.1 Class A0 ADS-B Transponder-Based Transmitter Power

The minimum RF peak output power for Class A0 ADS-B Transponder-Based equipment **shall** be 18.5 dBW (70 W).

2.2.2.1.1.2 Class A1S and A1 ADS-B Transponder-Based Transmitter Power

The minimum RF peak output power for Class A1S and A1 ADS-B Transponder-Based equipment **shall** be 21.0 dBW (125 W).

2.2.2.1.1.3 Class A2 ADS-B Transponder-Based Transmitter Power

The minimum RF peak output power for Class A2 ADS-B Transponder-Based equipment **shall** be 21.0 dBW (125 W).

2.2.2.1.1.4 Class A3 ADS-B Transponder-Based Transmitter Power

The minimum RF peak output power for Class A3 ADS-B Transponder-Based equipment **shall** be 23.0 dBW (200 W).

2.2.2.1.1.5 Class B ADS-B Transponder-Based Transmitter Power

The minimum RF peak output power for Class B0, B2 and B3 ADS-B Transponder-Based equipment **shall** be 18.5 dBW (70 W). The minimum RF peak output power for Class B1S and B1 ADS-B Transponder-Based equipment **shall** be 21.0 dBW (125 W).

2.2.2.1.2 RF Peak Output Power (maximum)

The maximum RF peak output power of each pulse of each transmitted message at the terminals of the antenna **shall** be fixed at 27.0 dBW (500 W) for all classes of Transponder-Based equipment.

2.2.2.2 Stand Alone Transmitters

Stand Alone Transmitters for Class A0 and Class B0 equipment are those implemented independent of a Mode S transponder. Such transmitters **shall** comply with the ADS-B requirements of the latest version of FAA TSO-C166 and **shall** meet the requirements specified in the following subparagraphs.

<u>Note:</u> *A 1090 MHz Non-Transponder-Device (NTD) is intended to provide the lowest cost implementation of Extended Squitter for low-end General Aviation (GA) users. A NTD implementation does not use the 1090 MHz spectrum as efficiently nor provide all of the system benefits as a Mode S Transponder implementation. For this reason, its use is restricted to class A0 operation in order to limit the number of such devices. Examples of the spectrum efficiency and system benefit issues related to NTDs are as follows:*

1. *<u>TCAS will not be able to benefit from the ADS-B information from the NTD.</u> TCAS will only monitor ADS-B data reported in DF=17 squitters (as emitted by a Mode S transponder). DF=18 squitters from NTDs are not monitored since TCAS must assume that it cannot interrogate the aircraft (via Mode S) to validate the range and approximate bearing via active interrogations through a process called hybrid surveillance.*

2. *Mode S interrogators will not be able to benefit from the ADS-B information from the NTD.* *Mode S interrogators will not be able to read Extended Squitter messages via direct air-ground readout. Such readout requires that the ADS-B data is available in the transponder registers. This will not be the case for a NTD.*

3. *More interference is generated.* *An aircraft equipped with a NTD and a Mode A/C transponder will generate more interference than a Mode S transponder implementation of Extended Squitter. Examples are as follows: (a) For a transponder implementation, TCAS will (after validation) maintain an aircraft on passive surveillance unless it becomes a near threat or a threat. For the NTD case, the aircraft will emit Extended Squitters and be regularly interrogated by TCAS. (b) A Mode S transponder implementation of Extended Squitter offers a surface surveillance system the possibility of controlling the squitter rate to reduce un-necessary transmissions.*

2.2.2.2.1 Transmission Frequency

The carrier frequency of ADS-B Message transmissions **shall** be 1090 ±1 MHz.

Note: *This requirement is consistent with ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.1, and RTCA DO-181D, §2.2.3.1 (EUROCAE ED-73C, §3.3.1).*

2.2.2.2.2 Transmission Spectrum

Spectrum requirements for the ADS-B transmitted message are provided in §2.2.3.1.3 and Table 2-7 of these MOPS.

Note: *The requirements provided are consistent with requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, § 3.1.2.2.2 and Figure 3-5, as well as with the requirements of RTCA DO-181D (EUROCAE ED-73C).*

2.2.2.2.3 Modulation

The ADS-B transmitted message **shall** consist of a preamble and a data block. The preamble **shall** be a 4-pulse sequence and the data block **shall** be binary pulse-position modulated at a 1 megabit per second data rate.

Note: *This requirement is consistent with ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.4. Requirements consistent with RTCA DO-181D, §2.2.4.2.1 (EUROCAE ED-73C, §3.6.1 and §3.6.2) are provided in §2.2.3.1.1 of this document.*

2.2.2.2.4 Pulse Shapes

Pulse shape requirements of the ADS-B transmitted message are provided in §2.2.3.1.3 of these MOPS.

Note: *The requirements provided are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.4.1 and Table 3-2, as well as with the requirements of RTCA DO-181D, §2.2.4.2.3 (EUROCAE ED-73C, §3.3.2 and §3.6.4).*

2.2.2.2.5 Message Structure

Message structure requirements of the ADS-B transmitted message are provided in §2.2.3.1 and Figure 2-1 of these MOPS.

Note: *The requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.5 and Figure 3-6, as well as with the requirements of RTCA DO-181D, §2.2.4.2 and Figure 2-3 (EUROCAE ED-73C, §3.6.1 and Figure 3-2).*

2.2.2.2.6 Pulse Intervals

Pulse interval requirements of the ADS-B transmitted message are provided in §2.2.3.1.4 of these MOPS.

Note: *The requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.5.1, as well as with the requirements of RTCA DO-181D, §2.2.4.2.4 (EUROCAE ED-73C, §3.6.5).*

2.2.2.2.7 Preamble

Preamble requirements of the ADS-B transmitted message are provided in §2.2.3.1.1 of these MOPS.

Note: *The requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, § 3.1.2.2.5.1.1, as well as with the requirements of RTCA DO-181D, § 2.2.4.2.1 (EUROCAE ED-73C, §3.6.1).*

2.2.2.2.8 Data Pulses

Requirements for data pulses of the ADS-B transmitted message are provided in §2.2.3.1.2 of these MOPS.

Note: *The requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.5.1.2, as well as with the requirements of RTCA DO-181D, §2.2.4.2.2 (EUROCAE ED-73C, §3.6.2).*

2.2.2.2.9 Pulse Amplitude

Pulse amplitude requirements of the ADS-B transmitted message are provided in §2.2.3.1.3 of these MOPS.

Note: *The requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.5.2, as well as with the requirements of RTCA DO-181D, §2.2.4.2.3 (EUROCAE ED-73C, §3.3.2 and §3.6.4.b).*

2.2.2.2.10 RF Peak Output Power

The RF peak output power requirements of each pulse of each transmitted message at the terminals of the antenna are provided in the following subparagraphs for each class of equipment addressed.

2.2.2.2.10.1 Class A0 and B0 Equipment RF Peak Output Power

The minimum RF peak output power for Class A0 and B0 equipment **shall**:

a. not be less than 18.5 dBW (70 W) for aircraft (or other installations) not capable of operating at altitudes exceeding 15000 feet (4570 meters);

b. not be less than 21.0 dBW (125 W) for aircraft (or other installations) capable of operating above 15000 feet (4570 meters);

c. not be less than 21.0 dBW (125 W) for aircraft (or other installations) with a maximum cruising speed exceeding 175 knots (324 km/h).

Note: *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.10.2, as well as with the requirements of RTCA DO-181D, §2.2.3.2 (EUROCAE ED-73C, §3.3.3).*

2.2.2.2.10.2 Class B2 and B3 Equipment RF Peak Output Power

The minimum RF peak output power for Class B2 and B3 equipment **shall not** be less than 18.5 dBW (70 W).

Notes:

1. *ADS-B equipment that meets all requirements of Class B2 with the exception of this RF peak output power requirement is identified by the use of the "B2 Low" Capability Class Code as specified in §2.2.3.2.7.2.3.8.*

2. *It is noted that the 70 W minimum RF peak output power requirement for Class B2 equipment is overly stringent to meet the 5NM operational range required for airport surface operations in RTCA DO-242A. Future revisions of these MOPS may reduce the minimum power output requirement on B2 equipment to better reflect the 5NM operational range.*

2.2.2.2.10.3 RF Peak Output Power (maximum)

The maximum RF peak output power of each pulse of each transmitted message at the terminals of the antenna **shall** be fixed at 27.0 dBW (500 W) for all classes of stand-alone transmitter based equipment.

Note: *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.10.2, as well as with the requirements of RTCA DO-181D, §2.2.3.2 (EUROCAE ED-73C, §3.3.3).*

2.2.2.2.11 Unwanted Output Power

When the ADS-B transmitter is in the inactive state, the RF output power at 1090 ±3.0 MHz at the terminals of the antenna **shall** not exceed -70 dBm.

Notes:

1. *The inactive state is defined to include the entire period between ADS-B Message transmissions less 10-microsecond transition periods, if necessary, preceding and following the extremes of the transmissions.*

2. *This unwanted power requirement is necessary to insure that the ADS-B transmitter does not prevent closely located 1090 MHz receiver equipment from meeting its requirements. It assumes that the isolation between the ADS-B transmitter antenna and the 1090 MHz receiver equipment antenna exceeds 20 dB. The resultant interference level at the 1090 MHz receiver equipment antenna should then be below -90 dBm.*

3. *This unwanted power requirement is consistent with the requirements provided in:*

a. ICAO, Annex 10, Volume 4, Fourth Edition, July 2007, §3.1.2.10.2.1.

b. RTCA DO-181D, §2.2.3.3 and §2.2.22.f (EUROCAE ED-73C, §3.3.4 and §3.27.f), and

c. RTCA DO-185B, §2.2.3.2 (EUROCAE ED-143, §2.2.3.2).

2.2.2.2.12 Broadcast Rate Capability

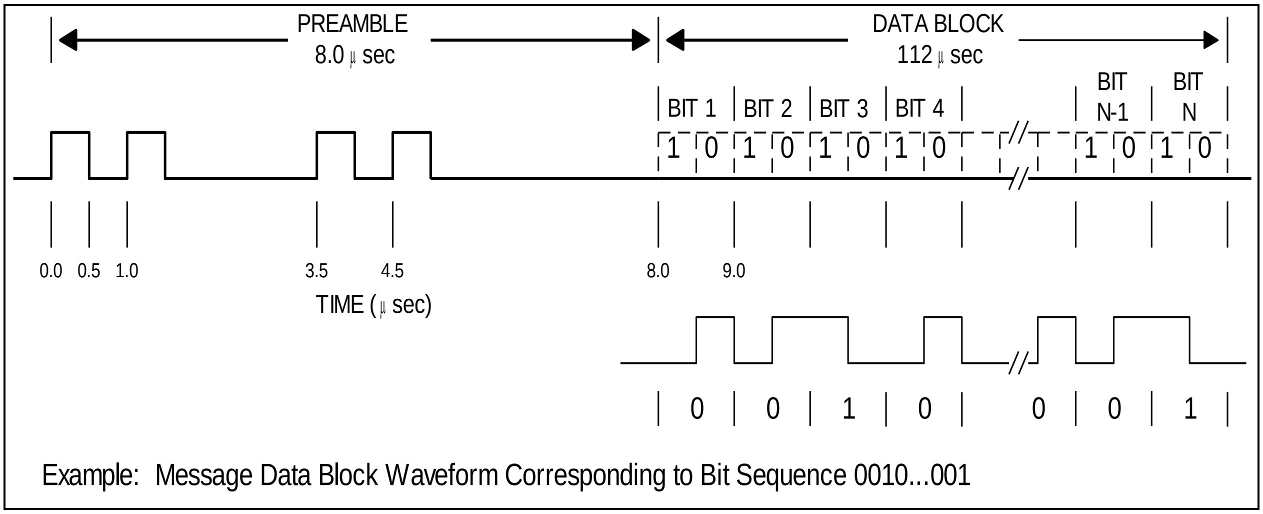
The ADS-B Transmitting Subsystem must be capable of the broadcast rates specified for each message type in §2.2.3.3. These rates must be maintained along with whatever other transmit functions that the transmitting device may be required to perform.

2.2.3 Broadcast Message Characteristics

2.2.3.1 ADS-B Message Characteristics

The ADS-B Message data block is formed by Pulse Position Modulation (PPM) encoding of the message data. A pulse transmitted in the first half of the interval represents a ONE while a pulse transmitted in the second half represents a ZERO (see Figure 2-1).

Note: *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.3.1.2, as well as with the requirements of RTCA DO-181D, §2.2.4.2 (EUROCAE ED-73C, §3.6).*



<u>Figure 2-1:</u> ADS-B Message Transmission Waveform

2.2.3.1.1 ADS-B Message Preamble

The preamble **shall** consist of 4 pulses, each having duration of 0.5 ±0.05 microseconds. The second, third and fourth pulses **shall** be spaced 1.0, 3.5 and 4.5 microseconds, respectively, from the first transmitted pulse. The spacing tolerance **shall** be in accordance with §2.2.3.1.4.

<u>Note:</u> *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.4 and §3.1.2.2.5, as well as with the requirements of RTCA DO-181D, §2.2.4.2 (EUROCAE ED-73C, §3.6.1).*

2.2.3.1.2 ADS-B Message Data Pulses

The block of message data pulses **shall** begin 8.0 microseconds after the first transmitted pulse. 112 one-microsecond intervals **shall** be assigned to each ADS-B Message transmission. A pulse with a width of 0.5 ±0.05 microseconds **shall** be transmitted either in the first or the second half of each interval. If a pulse transmitted in the second half of one interval is followed by another pulse transmitted in the first half of the next interval, the two pulses **shall** merge and a 1.0 ±0.05 microsecond pulse **shall** be transmitted.

<u>Note:</u> *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.5.1.2, as well as with the requirements of RTCA DO-181D, §2.2.4.2.2 (EUROCAE ED-73C, §3.6.2).*

2.2.3.1.3 ADS-B Message Pulse Shape

a. The pulse amplitude variation between one pulse and any other pulse in a message transmission **shall not** exceed 2 dB.

b. The pulse rise time **shall not** be less than 0.05 microseconds or greater than 0.1 microsecond.

c. The pulse decay time **shall not** be less than 0.05 microseconds or greater than 0.2 microseconds.

d. The spectrum of the message transmission **shall not** exceed the bounds in Table 2-7:

Table 2-7: ADS-B Transmission Message Spectrum

Frequency Difference (MHz from 1090 MHz)	**Maximum Relative Response** (dB Down From Peak)
> 1.3 and ≤ 7	3
> 7 and ≤ 23	20
> 23 and ≤ 78	40
> 78	60

Note: *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2, Table 3-2, and Figure 3-5, as well as with the requirements of RTCA DO-181D, §2.2.4.2.2 (EUROCAE ED-73C, §3.6.4).*

2.2.3.1.4 ADS-B Message Pulse Spacing

ADS-B Message transmission pulses **shall** start at a defined multiple of 0.5 microsecond from the first transmitted pulse. The pulse position tolerance **shall** be ±0.05 microseconds, measured from the first pulse of the transmission.

Note: *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.2.5.1, as well as with the requirements of RTCA DO-181D, §2.2.4.2.4 (EUROCAE ED-73C, §3.6.5).*

2.2.3.2 ADS-B and TIS-B Message Baseline Format and Structures

Figure 2-2 shows the overall format structure that **shall** be used for ADS-B and TIS-B Messages. The first 5 data bits in each transmission are called the DF (Downlink Format) field, while the next three bits are called:

1. the CA field if DF=17,

2. the CF field if DF=18, or

3. the AF field if DF=19.

<table>
<tr><th colspan="6">ADS-B and TIS-B Overall Message Format Structures</th></tr>
<tr><td>Bit # →</td><td>1 ------ 5</td><td>6 ------ 8</td><td>9 ------ 32</td><td>33 ------ 88</td><td>89 ------ 112</td></tr>
<tr><td>DF=17 Field Names →</td><td>DF=17
[5]</td><td>CA
[3]</td><td>AA
ICAO Address
[24]</td><td>ADS-B Message ME Field
[56]</td><td>PI
[24]</td></tr>
<tr><td rowspan="7">DF=18 Field Names →</td><td rowspan="7">DF=18
[5]</td><td>CF=0
[3]</td><td>AA
ICAO Address
[24]</td><td rowspan="2">ADS-B Message ME Field
[56]</td><td rowspan="2">PI
[24]</td></tr>
<tr><td>CF=1
[3]</td><td>AA
non-ICAO
Address
[24]</td></tr>
<tr><td>CF=2 to 3
[3]</td><td>AA
[24]</td><td>TIS-B Message ME Field
[56]</td><td>PI
[24]</td></tr>
<tr><td>CF=4
[3]</td><td colspan="2">TIS-B and ADS-R Management Messages</td><td>PI
[24]</td></tr>
<tr><td>CF=5
[3]</td><td>AA
non-ICAO
Address
[24]</td><td>TIS-B Message ME Field
[56]</td><td rowspan="3">PI
[24]</td></tr>
<tr><td>CF=6
[3]</td><td colspan="2">Rebroadcast of an ADS-B Message from an alternate data link using the same TYPE Codes and Message Formats as are defined for DF=17 ADS-B Messages, with the exception of bits modified as identified in §2.2.18.</td></tr>
<tr><td>CF=7</td><td colspan="2">Reserved</td></tr>
<tr><td rowspan="2">DF=19 Field Names→</td><td rowspan="2">DF=19
[5]</td><td>AF=0
[3]</td><td>AA
ICAO Address
[24]</td><td>ADS-B Message ME Field
[56]</td><td>PI
[24]</td></tr>
<tr><td>AF=1 to 7
[3]</td><td colspan="3">Reserved for Military Applications</td></tr>
<tr><td></td><td>MSB LSB</td><td>MSB LSB</td><td>MSB LSB</td><td>MSB LSB</td><td>MSB LSB</td></tr>
</table>

<u>Figure 2-2:</u> ADS-B and TIS-B Message Baseline Format Structure

<u>Notes for Figure 2-2:</u>

1. *"[#]" provided in a field indicates the number of bits in the field.*

2. *DF=19 messages are intended for Military Applications systems only.*

3. *For DF=19, if the AF field is equal to 0, then bits 9-32 are used for the AA field, bits 33-88 are used for the ME field, and bits 89-112 are used for the PI field. If the AF field is not 0 (that is, is in the range 1 to 7) then bits 9-112 are used for the "Reserved for Military Applications" field. (This format is reserved for military use only.)*

The DF=17 format is used for ADS-B Messages from Mode S transponders. If DF=17, the CA field describes the capabilities of the Mode S transponder, the AA field holds the transponder's 24-bit ICAO address, the ME field holds the body of the ADS-B Message, and the PI field holds parity check bits.

The DF=18 format is used for ADS-B or TIS-B Messages from transmitting devices that are not Mode S transponders. If DF=18, then the 3-bit CF (Code Format) field designates whether the ME field holds an ADS-B Message or a TIS-B Message. For DF=18 transmissions in which CF=0 or 1 (that is, DF=18 Extended Squitters that carry ADS-B Messages), the CF field also specifies what type of address is contained in the AA field.

ADS-B Messages **shall** use Extended Squitter formats in which DF=17, or in which DF=18 and CF=0 or 1, or in which DF=19 and AF=0. The DF=19 format is reserved for military applications; non-military ADS-B participants **shall not** transmit Extended Squitter formats in which DF=19.

ADS-B Airborne Receiving Subsystems **shall** accept, and process as ADS-B Messages, any Extended Squitter transmissions in which DF=17, or in which DF=18 and CF=0, 1 or 6. ADS-B Airborne Receiving Subsystems may accept and process ADS-B Messages in which DF=19 and AF=0, but need not do so. ADS-B Airborne Receiving Subsystems **shall not** process as ADS-B Messages any Extended Squitter receptions in which DF=18 and CF is not equal to 0, 1 or 6, or any Extended Squitter receptions in which DF=19 and AF is not equal to 0.

TIS-B Messages use 1090 MHz Extended Squitter formats in which DF=18 and CF=2, 3 or 5. An ADS-B Message from an alternate data link that is being rebroadcast by ground equipment as a Message using the 1090 MHz Extended Squitter uses formats in which DF=18 and CF=6, and the same TYPE Codes and Message formats as are defined for DF=17 ADS-B Messages, with the exception of bits modified as identified in Section §2.2.18. 1090 MHz Extended Squitter Messages with DF=18 and CF=4 convey management information for TIS-B and ADS-R. Receiving equipment **shall not** process as TIS-B Messages any Extended Squitter receptions in which DF is not equal to 18, or in which CF is not in the range from 2 to 5.

Note: *A primary purpose of the TIS-B/ADS-R Management Messages (i.e., DF=18 and CF=4) is to convey the TIS-B and the ADS-R service volumes and to provide a 'heartbeat' indicator. This information is provided in order that airborne applications using TIS-B and/or ADS-R received information can determine if their own ship is within the designated TIS-B and/or ADS-R service volume (i.e., by comparing own ship position with the service volume information conveyed by the management message) and current service availability (i.e., with the 'heartbeat' function conveyed by the management message). Although the explicit data contents of the TIS-B/ADS-R Management Messages are not defined within this document, the overall message structure and purpose is defined*.

2.2.3.2.1 ADS-B Message Baseline Field Descriptions

The following subparagraphs describe the fields that were listed in Figure 2-2 above.

2.2.3.2.1.1 "DF" Downlink Format Field

a. The "DF" field is the first field in all downlink formats and provides the transmission descriptor coded in accordance with RTCA DO-181D, Figure 2-5 (EUROCAE ED-73C, Figure 3-4).

b. The "DF" field **shall** be set to DF=17 (binary 1 0001) for all ADS-B Message transmissions from Mode-S Transponder-Based transmission devices.

c. The "DF" field **shall** be set to DF=18 (binary 1 0010) for all ADS-B Message transmissions from transmission devices that are not Mode-S Transponder-Based systems. The DF=18 is also used for all TIS-B Message transmissions.

d. The "DF" field **shall** be set to DF=19 (binary 1 0011) for all ADS-B Message transmissions from transmission devices that are Military Application based systems.

Note: *Encoding of the "DF" field is consistent with §3.1.2.3.2 and Figure 3-8 in ICAO ANNEX 10, Volume IV, Fourth Edition, July 2007.*

2.2.3.2.1.2 "CA" Capability Field (used in DF=17)

a. Definition: -- The "CA" field is a 3-bit (Message bits 6 through 8) field used to report the capability of an ADS-B transmitting installation that is based on a Mode-S transponder. The "CA" field is used to report the capability and notice of a transponder condition that requires interrogation by the ground of a transponder. It is used in Mode-S downlink format DF=11, i.e., the Mode-S All Call reply and acquisition squitter, and DF=17. Therefore, the codes used in the "CA" field are as specified in Table 2-8:

Table 2-8: "CA" Field Code Definitions

Coding (Binary)	Coding (Decimal)	Meaning
000	0	Signifies Level 1 transponder (surveillance only), and no ability to set "CA" code 7, and either on the ground or airborne
001	1	Reserved
010	2	Reserved
011	3	Reserved
100	4	Signifies Level 2 or above transponder, and the ability to set "CA" code 7, and on the ground
101	5	Signifies Level 2 or above transponder, and the ability to set "CA" code 7, and airborne
110	6	Signifies Level 2 or above transponder, and the ability to set "CA" code 7, and either on the ground or airborne
111	7	Signifies the "DR" field is NOT equal to ZERO (0), or the "FS" field equals 2, 3, 4, or 5, and either on the ground or airborne.

When the conditions for "CA" Code 7 are not satisfied, Level 2 or above transponders in installations that do not have automatic means to set on-the-ground condition **shall** use "CA" Code 6. Aircraft with automatic on-the-ground determination **shall** use "CA" Code 4 when on the ground, and "CA" Code 5 when airborne. Data Link capability reports (RTCA DO-181D, §2.2.19.1.12.6) (EUROCAE ED-73C, §3.23.1.12.e) **shall** be available from aircraft installations that set "CA" codes 4, 5, 6 and 7.

Notes:

1. *"CA" codes 1 to 3 are reserved to maintain backward compatibility.*

2. *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, §3.1.2.5.2.2.1, as well as with the requirements of RTCA DO-181D, §2.2.14.4.6 (EUROCAE ED-73C, §3.18.4.5).*

b. Transponder Use -- The "CA" code definitions provided herein are intended for use when implemented with the Mode-S Transponder functions.

c. Air/Ground Determination

(1). If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's Emitter Category (§2.2.3.2.5.2) is one of the following, then it **shall** set its Air/Ground State to "Airborne," and broadcast the Airborne Position Message (§2.2.3.2.3):

- Unknown Emitter Category
- Light Aircraft
- Rotorcraft
- Glider or Sailplane
- Lighter Than Air
- Unmanned Aerial Vehicle
- Ultralight, Hang Glider or Paraglider
- Parachutist or Skydiver
- Point Obstacle
- Cluster Obstacle
- Line Obstacle

Notes:

1. *Because of the unique operating capabilities of "Lighter-Than-Air" vehicles, i.e., balloons, an operational "Lighter-Than-Air" vehicle will always report the "Airborne" State, unless the "ON-GROUND" State is specifically declared in compliance with subparagraph "(4)" below.*
2. *Because of the fact that it is important for Fixed Ground or Tethered Obstacles to report altitude, such objects will always report the "Airborne" state.*
3. *Because of the unique capabilities of Rotorcraft, i.e., hover, etc., an operational Rotorcraft will always report the "Airborne" state unless the "ON-GROUND" state is specifically declared in compliance with subparagraph "(4)" below.*
4. *An automatic means of determining air/ground status may include Weight-on-Wheels discrete, Airspeed, Ground Speed, Radio Altitude, or other appropriate data sources.*

(2). If a transmitting ADS-B participant's Emitter Category (§2.2.3.2.5.2) is one of the following, then that participant **shall** set its Air/Ground State to the "ON-GROUND" condition and broadcast the Surface Position Message (§2.2.3.2.4):

- Surface Vehicle – Emergency
- Surface Vehicle – Service

(3). If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and its ADS-B Emitter Category (§2.2.3.2.5.2) is not one of those listed under tests (1) or (2) above (i.e., the participant's Emitter Category is either: Small, Large, High Vortex Large, Heavy, Highly Maneuverable, or Space/Trans-Atmospheric), then the following tests will be performed to determine whether to broadcast the Airborne or Surface Position Messages.

a. If the participant's Radio Height (RH) parameter is available, and RH<50 feet, and at least Ground Speed (GS) or Airspeed (AS) is available, and the available GS<100 knots, or the available AS<100 knots, then that participant **shall** broadcast the Surface Position Message (§2.2.3.2.4).

   If all three parameters are available, the decision to broadcast the Airborne or Surface Position Messages **shall** be determined by the logical "AND" of all three parameters.

b. Otherwise, if Radio Height (RH) is not available, and if the participant's Ground Speed (GS) and Airspeed (AS) are available, and GS<50 knots and AS<50 knots, then that participant **shall** broadcast the Surface Position Message (§2.2.3.2.4).

c. Otherwise, the participant **shall** broadcast the Airborne Position Message (§2.2.3.2.3).

(4). If a transmitting ADS-B participant is equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, then such information **shall** be used to determine whether to broadcast the Airborne Position Message (§2.2.3.2.3), or the Surface Position Message (§2.2.3.2.4).

d. Validation of Ground Status:

Note: *For aircraft with an automatic means of determining vertical status (i.e., weight-on-wheels, strut switch, etc.) the "CA" field reports whether the aircraft is airborne or on the ground. TCAS acquires aircraft using the acquisition squitters or extended squitters, both of which contain the "CA" field. If an aircraft reports that it is on the ground, that aircraft will not be interrogated by TCAS in order to reduce unnecessary interrogation activity. The 1090 MHz ADS-B Message formatter may have information available to validate that an aircraft reporting "on-the-ground" is actually on the surface.*

If the automatically determined Air/Ground status is not available or indicates that the Airborne Position Message (see §2.2.3.2.3) **shall** be broadcast, then the Airborne Position Message **shall** be broadcast in accordance with subparagraph c.

If one of the conditions in Table 2-10 is satisfied, then the Air/Ground status **shall** be changed to "Airborne" and the Airborne Position Message (see §2.2.3.2.3) **shall** be broadcast irrespective of the automatically determined Air/Ground status.

Table 2-10: Validation of "ON-GROUND" Status

Airborne Position Message Broadcast						
ADS-B Emitter Category Set "A"		**Ground Speed**		**Airspeed**		**Radio Altitude**
Coding	**Meaning**					
0	No ADS-B Emitter Category Information	No Change to "On-the-Ground" status				
1	Light (<15,500 lbs.)	No Change to "On-the-Ground" status				
2	Small (15,500 to 75,000 lbs.)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
3	Large (75,000 to 300,000 lbs.)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
4	High-Vortex Large (aircraft such as B-757)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
5	Heavy (> 300,000 lbs.)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
6	High Performance (> 5g acceleration and >400 knots)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
7	Rotorcraft	No Change to "On-the-Ground" status				

Notes:

1. *Aircraft reporting ADS-B Emitter Category Set "A" codes 0, 1 or 7 with an automatic means to determine the on-the-ground status, and means to validate that status, may change the status to "Airborne" if the on-the-ground status cannot be validated.*

2. *Modern aircraft with integrated avionics suites commonly contain sophisticated algorithms for determining the air/ground status based on multiple aircraft sensors. These algorithms are customized to the airframe and designed to overcome individual sensor failures. These algorithms are an acceptable means to determine the air/ground status and do not require additional validation.*

2.2.3.2.1.3 "CF" Field (used in DF=18)

The "CF" field of DF=18 messages is a 3-bit field (Message bits 6 through 8) used by installations in which the ADS-B or TIS-B transmitting device is not based on a Mode S transponder. The CF field serves to classify DF=18 messages between ADS-B Messages and TIS-B Messages. For ADS-B Messages, the CF field also specifies whether or not the AA field (§2.2.3.2.1.5) holds a 24-bit ICAO address. For TIS-B Messages, the CF field serves to categorize the TIS-B Message as being a "fine format" TIS-B Message, a "coarse format" TIS-B Airborne Position and Velocity Message, a Fine TIS-B Message that uses non-ICAO 24-bit addresses, or a TIS-B/ADS-R Management Message. The coding of the CF field shall be as specified in Table 2-11.

Table 2-11: "CF" Field Code Definitions

Coding (Binary)	Coding (Decimal)	Meaning	
000	0	ADS-B Message	AA field holds the transmitting ADS-B Participant's 24-bit ICAO address.
001	1	ADS-B Message	AA field holds another kind of address for the transmitting ADS-B Participant: a self-assigned "anonymous" address, a ground vehicle address, or a surface obstruction address.
010	2	TIS-B and ADS-R Messages	Fine TIS-B Message using ICAO 24-bit address
011	3	TIS-B and ADS-R Messages	Coarse TIS-B Airborne Position and Velocity Message.
100	4	TIS-B and ADS-R Messages	TIS-B and ADS-R Management Messages.
101	5	TIS-B and ADS-R Messages	Fine TIS-B Message using non-ICAO 24-bit address
110	6	TIS-B and ADS-R Messages	Rebroadcast of an ADS-B Message from an alternate data link using the same TYPE Codes and Message Formats as are defined for DF=17 ADS-B Messages, with the exception of bits modified as identified in Section §2.2.18.
111	7	Reserved	

ADS-B Messages from ADS-B Transmitting Subsystems that are not based on Mode S transponders **shall** use CF=0 or 1, according to the type of address conveyed in the AA field. TIS-B Messages use CF=2, 3 or 5. An ADS-B Message from an alternate data link that is being Rebroadcast by ground equipment as a Message using 1090 MHz Extended Squitter uses formats in which DF=18 and CF=6, and the same 1090ES TYPE Codes and Message formats as are defined for DF=17 ADS-B Messages, with the exception of bits modified as identified in section §2.2.18. CF code 7 is reserved for future standardization and **shall not** be transmitted by equipment that conforms to these MOPS (RTCA DO-260B).

2.2.3.2.1.4 "AF" Field (used in DF=19)

The "AF" ("Application Field") field of DF=19 messages is a 3-bit field (Message bits 6 through 8) used by all ADS-B Message transmissions from transmission devices that are Military Application based systems. The coding of the "AF" field **shall** be as specified in Table 2-12. Refer to §2.2.3.2.1.2 for determining On-Ground Status.

Table 2-12: "AF" Field Code Definitions

Coding (Binary)	Coding (Decimal)	Meaning
000	0	ADS-B Message Structure
001 - 111	1 - 7	Reserved for future Military Applications

2.2.3.2.1.5 "AA" Address Field, Announced

The "AA" field is a 24-bit (Message bits 9 through 32) field that **shall** contain the address of the transmitting installation. This is intended to provide unambiguous identification of the A/V being described in the ADS-B or TIS-B Message.

The type of address (whether a 24-bit ICAO address or some other kind of address) contained in the AA field depends on the value of the DF field, and the CF or AF fields when DF=18 or 19, and the IMF (ICAO/Mode A flag) subfield of the ME field for TIS-B Messages. The type of address in the AA field **shall** be as specified in Table 2-13.

Table 2-13: Determining The Type of Address in the AA Field

DF Field	CF or AF Field	IMF Subfield	AA Field Contents
17	N/A	N/A	24-bit ICAO address of transmitting ADS-B Participant
18	CF=0	N/A	24-bit ICAO address of transmitting ADS-B Participant
	CF=1		Anonymous address or ground vehicle address or fixed obstacle address of transmitting ADS-B Participant
	CF=2	0	TIS-B target's 24-bit ICAO address
		1	TIS-B target's 12-bit Mode A code and track file number
	CF=3	0	TIS-B target's 24-bit ICAO address
		1	TIS-B target's 12-bit Mode A code and track file number
	CF=4	N/A	TIS-B and ADS-R Management Messages; AA field contains TIS-B/ADS-R management information
	CF=5	0	TIS-B target's 24-bit non-ICAO address
		1	Reserved
	CF=6	0	24-bit ICAO Address of the transmitting ADS-B Participant
		1	Anonymous address or ground vehicle address or fixed obstacle address of the transmitting ADS-B Participant
	CF=7	N/A	Reserved for future standardization; AA field does not necessarily exist in messages for which DF=18 and CF is equal to 7.
19	AF=0	N/A	24-bit ICAO address of transmitting ADS-B participant
	AF=1 to 7		Reserved for military use; AA field does not necessarily exist in messages for which DF= 19 and AF is in the range from 1 to 7.

For Extended Squitter transmissions in which DF=17, or in which DF=18 and CF=0, or in which DF=19 and AF=0, the AA field contains the 24-bit ICAO address of the transmitting participant.

The TIS-B/ADS-R Management Messages (i.e., DF=18 and CF=4) do not relate to an aircraft but rather relate to the coverage and availability of the TIS-B or ADS-R service that is being provided by the local ground infrastructure. Therefore, the coding of the AA field for TIS-B/ADS-R Management Messages is used to convey additional information in the TIS-B/ADS-R Management Message and must be included in the data delivered to ADS-B applications.

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Notes:

1. *For Extended Squitter transmissions in which DF=18 and CF=1, the CF field indicates that the ME field holds an ADS-B Message and that the AA field holds an address other than the standard ICAO 24-bit address of the transmitting ADS-B participant.*

2. *For Extended Squitter transmission in which DF=18 and CF=2, 3 or 5, the CF field indicates that the ME field holds a TIS-B Message. In these cases, the meaning of the AA field – whether or not it contains the ICAO 24-bit address of the aircraft being described in the TIS-B Message – depends on the value of the CF field, as described in §0.*

3. *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, as well as the requirements of RTCA DO-181D, §2.2.14.4.1 (EUROCAE ED-73C, §3.18.4.1).*

The ADS-B transmitter **shall** declare a transmitter failure in the event that its own ICAO 24-bit Address is all "ZEROs" or all "ONEs."

Note: *This requirement is consistent with the requirements of RTCA DO-181D, §2.2.10.3.*

2.2.3.2.1.6 "ME" Message, Extended Squitter

The "ME" field is a 56-bit field (Message bits 33 through 88) that occurs in every 1090 MHz Extended Squitter Message (that is, in the relevent messages specified in Figure 2-2). The ME field carries the bulk of the data in ADS-B and TIS-B Messages.

The first five bits of the ME field comprise the TYPE Code subfield. For certain values of the TYPE Code subfield, the next three bits ("ME" bits 6 to 8) comprise a Subtype Code subfield. The values in the TYPE subfield and, if present, the Subtype subfield, determine which of several ADS-B or TIS-B Messages is being conveyed in the remainder of the "ME" field. The TYPE and Subtype subfields are described in §2.2.3.2.2.

The "ME" field formats for the various ADS-B Messages are described in §2.2.3.2.3 through §2.2.3.2.7 below. The formats for the various TIS-B Messages are described in §2.2.17 and its subparagraphs.

2.2.3.2.1.7 "PI" Parity / Identity

The "PI" field is a 24-bit (Message bits 89 through 112) downlink field that contains the parity overlaid on the Code Label ("CL") and Interrogator Code ("IC") fields, that **shall** be in accordance with §2.2.14.4.30 and §2.2.18.2.1 of RTCA Document DO-181D (EUROCAE ED-73C, §3.18.4.27 and §3.22.2.1).

Note: *In ADS-B and TIS-B Messages (those transmitted with downlink format DF=17, or with DF=18 and CF in the range from 0 to 6, or with DF=19 and AF=0) both CL=0 and IC=0. In other words, in ADS-B and TIS-B Messages the parity is overlaid with a 24-bit pattern of ALL ZEROs.*

2.2.3.2.2 Determining ADS-B and TIS-B Message Types

All ADS-B and TIS-B transmissions have the baseline structure specified in §2.2.3.2.1. The subfields of the "ME" field are defined for each of the ADS-B Message types in the following subparagraphs.

In ADS-B and TIS-B Extended Squitter Messages, the TYPE Code subfield of the "ME" field occupies "ME" bits 1 to 5 (Message bits 33 to 37). The Subtype field, if present for a particular message type, occupies "ME" bits 6 to 8 (Message bits 38 to 40). The "TYPE Code" subfield, together with the "Subtype" subfield for some message types, is used to identify the ADS-B or TIS-B Message and to differentiate the messages into several message types.

The format TYPE Code differentiates the 1090ES Messages into several classes: Airborne Position, Airborne Velocity, Surface Position, Identification and Category, Aircraft Intent, Aircraft Status, etc. In addition, the format TYPE Code also encodes the Navigation Integrity Category (NIC) value of the source used for the position report. The NIC value is used to allow surveillance applications to determine whether the reported geometric position has an acceptable level of integrity containment region for the intended use. The NIC integrity containment region is described horizontally using the Radius of Containment (R_C). The format TYPE Code also differentiates the Airborne Messages as to the type of their altitude measurements: barometric pressure altitude or GNSS height (HAE). The 5-bit encoding for the format TYPE Code and NIC values conforms to the definition contained in Table 2-16. If an update has not been received from an on-board data source to allow for the determination of the NIC value within the past 5 seconds, then the NIC value is encoded to indicate that R_C is "Unknown."

For ADS-B Messages (those for which DF=17, or DF=18 and CF=0, 1 or 6, or DF=19 and AF=0), the possible Message Types are those listed in Table 2-14. An ADS-B Message from an alternate data link that is being Rebroadcast by ground equipment using 1090 MHz Extended Squitter uses formats in which DF=18 and CF=6, and uses the same 1090ES TYPE Codes and Message formats as are defined for DF=17 ADS-B Messages, with the exception of bits modified as identified in section §2.2.18. In Table 2-14, the word "***Reserved***" indicates ADS-B Message Types for which ADS-B Message formats have not yet been defined, but which may be defined in future versions of these MOPS. The TYPE Code, together with the Subtype Code (if present for a given TYPE Code value), identifies the TYPE of ADS-B Message being broadcast, in accordance with Table 2-14.

Note: *ADS-B Receiving Subsystems should not generate ADS-B Reports based on the receipt of ADS-B Message Types that are indicated as "**Reserved**" in Table 2-14.*

Table 2-14: Determining ADS-B Message Type (DF=17 or DF=18 and CF=0, 1 or 6, or DF=19 and AF=0)

TYPE Code ("ME" bits 1-5)	Subtype Code ("ME" bits 6-8)	ADS-B Message Type
0	Not Present	Airborne Position Message (§2.2.3.2.3), Surface Position Message (§2.2.3.2.4)
1 – 4	Not Present	Aircraft Identification and Category Message (§2.2.3.2.5)
5 – 8	Not Present	Surface Position Message (§2.2.3.2.4)
9 - 18	Not Present	Airborne Position Message (§2.2.3.2.3)
19	0	Reserved
	1 – 4	Airborne Velocity Message (§2.2.3.2.6)
	5 – 7	Reserved
20 - 22	Not Present	Airborne Position Message (§2.2.3.2.3)
23	0	Test Message (§2.2.3.2.7.3)
	1 – 7	Reserved
24	0	Reserved
	1	Surface System Status (§2.2.3.2.7.4) (Allocated for National use)
	2 – 7	Reserved
25 – 26		Reserved
27		Reserved for Trajectory Change Message (§2.2.3.2.7.7)
28	0	Reserved
	1	Extended Squitter Aircraft Status Message (Emergency/Priority Status & Mode A Code) (§2.2.3.2.7.8.1)
	2	Extended Squitter Aircraft Status Message (1090ES TCAS RA Message) (§2.2.3.2.7.8.2)
	3 – 7	Reserved
29	0	Target State and Status defined in DO-260A, ADS-B Version=1
	1	Target State and Status (§2.2.3.2.7.1)
	2 – 3	Reserved
30	0 – 7	Reserved
31	0 – 1	Aircraft Operational Status (§2.2.3.2.7.2)
	2 – 7	Reserved

For TIS-B Messages (those for which DF=18 and CF is in the range from 2 to 5), the possible message Types are specified in Table 2-15. In that table, the word "***Reserved***" indicates TIS-B Message Types for which the message formats have not yet been defined, but which may be defined in future versions of these MOPS. The TYPE Code, together with the Subtype Code (if present for a given TYPE Code value), identifies the Type of TIS-B Message being received, in accordance with Table 2-15.

Note: *TIS-B Receiving Subsystems should not generate TIS-B Reports based on the receipt of messages for which the TIS-B Message Type is indicated as "**Reserved**" in Table 2-15.*

Table 2-15: Determining TIS-B or ADS-R Message Type (DF=18, CF=2 to 6)

CF Field Value	TYPE Code ("ME" bits 1-5)	Subtype Code ("ME" bits 6-8)	TIS-B Message Type
2 or 5	0	Not Present	TIS-B Fine Airborne Position Message (§2.2.17.3.1), or TIS-B Fine Surface Position Message (§2.2.17.3.2)
	1 – 4	Not Present	TIS-B Identification and Category Message (§2.2.17.3.3)
	5 – 8	Not Present	TIS-B Fine Surface Position Message (§2.2.17.3.2)
	9 – 18	Not Present	TIS-B Fine Airborne Position Message (§2.2.17.3.1)
	19	0	Reserved
		1 – 4	TIS-B Velocity Message (§2.2.17.3.4)
		5 – 7	Reserved
	20 – 22	Not Present	TIS-B Fine Airborne Position Message (§2.2.17.3.1)
	23 – 31	Not Present	Reserved
3	Not Present	Not Present	TIS-B Coarse Airborne Position and Velocity Message (§2.2.17.3.5)
4	Not Present	Not Present	TIS-B and ADS-R Management Messages
6	0 – 31	See Table 2-14	ADS-B Rebroadcast (ADS-R) Message (§2.2.18)

2.2.3.2.3 ADS-B Airborne Position Messages

Format for the Airborne Position Message "ME" field contents **shall** be as specified in Figure 2-3. Each of the subfields is specified in the following subparagraphs.

Airborne Position Message "ME" Field								
Msg Bit #	33 -37	38 ---------- 39	40	41 ----- 52	53	54	55 ---- 71	72 ---- 88
"ME" Bit #	1 – 5	6 ------------ 7	8	9 ----- 20	21	22	23 --- 39	40 --- 56
Field Name	**TYPE Code [5]**	**Surveillance Status [2]**	**NIC Supplement-B [1]**	**Altitude [12]**	**Time (T) [1]**	**CPR Format (F) [1]**	**CPR Encoded Latitude [17]**	**CPR Encoded Longitude [17]**
	MSB LSB	MSB LSB		MSB LSB			MSB LSB	MSB LSB

Note: *"[#]" provided in the Field indicates the number of bits in the field.*

Figure 2-3: ADS-B Airborne Position Message Format

2.2.3.2.3.1 "TYPE" Code Subfield in ADS-B Airborne Position Messages

The "TYPE" Code subfield is a 5-bit ("ME" bits 1 through 5, Message bits 33 through 37) field that **shall** be used to identify the ADS-B Message and to differentiate between several message types.

1. Airborne Position Message (§2.2.3.2.3)
2. Surface Position Message (§2.2.3.2.4)
3. Aircraft Identification (ID) and Category Message (§2.2.3.2.5)
4. Airborne Velocity Message (TYPE=19) (§2.2.3.2.6)
5. Target State and Status Message (TYPE=29) (§2.2.3.2.7.1)
6. Aircraft Operational Status Message (TYPE=31) (§2.2.3.2.7.2)
7. Test Message (TYPE=23) (§2.2.3.2.7.3)
8. Aircraft Status Message (TYPE=28) (§2.2.3.2.7.8)

In the case of ADS-B Airborne Position Messages (§2.2.3.2.3), the Message TYPE Code subfield (§2.2.3.2.2) is also used in the following ways:

a. The TYPE Code subfield indicates the altitude type (barometric pressure altitude, §2.2.3.2.3.4.1, or geometric altitude, §2.2.3.2.3.4.2) being communicated in the Airborne Position Message.

b. Together with the NIC Supplement subfield (described in conjunction with the Aircraft Operational Status Message, §2.2.3.2.7.2.6), the TYPE Code subfield allows the encoding of the Navigation Integrity Category (NIC) (see Table 2-70).

For Surface Position Messages (§2.2.3.2.4), the TYPE Code subfield, together with the NIC Supplement, allows the encoding of the NIC – but not altitude type, since altitude is not reported in Surface Position Messages.

Detailed definition of the "TYPE" Code subfield encodings that **shall** be used for all ADS-B Airborne Position and Surface Position Messages are provided in Table 2-16. For Airborne Position Messages and Surface Position Messages, Table 2-16 also shows how the NIC value can be determined from the value of the TYPE Code subfield and the NIC Supplement subfield in the Airborne Position and Operational Status Messages.

The ADS-B Airborne Position Messages **shall** use only "TYPE" Code values 0, 9 through 18, and TYPE Codes 20 through 22 as indicated in Table 2-16.

Table 2-16: "TYPE" Subfield Code Definitions (DF=17 or 18)

TYPE Code	Subtype Code	NIC Supplement A	NIC Supplement B	NIC Supplement C	Format (Message Type)	Horizontal Containment Radius Limit (R_C)	Navigation Integrity Category (NIC)	Altitude Type	Notes
0	Not Present	*Not Applicable*			No Position Information (**Airborne or Surface Position Messages**)	R_C unknown	NIC = 0	Baro Altitude or No Altitude Information	1, 2, 3
1	Not Present	*Not Applicable*			**Aircraft Identification and Category Message** (§2.2.3.2.5)	*Not Applicable*	*Not Applicable*	*Not Applicable*	Category Set D
2									Category Set C
3									Category Set B
4									Category Set A
5	Not Present	0	--	0	**Surface Position Message** (§2.2.3.2.4)	$R_C < 7.5$ m	NIC = 11	No Altitude Information	
6		0	--	0		$R_C < 25$ m	NIC = 10		
7		1	--	0		$R_C < 75$ m	NIC = 9		6
		0	--	0		$R_C < 0.1$ NM (185.2 m)	NIC = 8		
8		1	--	1		$R_C < 0.2$ NM (370.4 m)	NIC = 7		
		1	--	0		$R_C < 0.3$ NM (555.6 m)	NIC = 6		
		0	--	1		$R_C < 0.6$ NM (1111.2 m)	NIC = 6		
		0	--	0		$R_C \geq 0.6$ NM (1111.2 m) or unknown	NIC = 0		
9	Not Present	0	0	--	**Airborne Position Message** (§2.2.3.2.3)	$R_C < 7.5$ m	NIC = 11	Baro Altitude	5
10		0	0	--		$R_C < 25$ m	NIC = 10		5
11		1	1	--		$R_C < 75$ m	NIC = 9		5, 6
		0	0	--		$R_C < 0.1$ NM (185.2 m)	NIC = 8		
12		0	0	--		$R_C < 0.2$ NM (370.4 m)	NIC = 7		
13		0	1	--		$R_C < 0.3$ NM (555.6 m)	NIC = 6		
		0	0	--		$R_C < 0.5$ NM (925 m)	NIC = 6		
		1	1	--		$R_C < 0.6$ NM (1111.2 m)			
14		0	0	--		$R_C < 1.0$ NM (1852 m)	NIC = 5		
15		0	0	--		$R_C < 2$ NM (3.704 km)	NIC = 4		
16		1	1	--		$R_C < 4$ NM (7.408 km)	NIC = 3		7
		0	0	--		$R_C < 8$ NM (14.816 km)	NIC = 2		
17		0	0	--		$R_C < 20$ NM (37.04 km)	NIC = 1		
18		0	0	--		$R_C \geq 20$ NM (37.04 km) or unknown	NIC = 0		
19	0	*Not Applicable*			Reserved	*Not Applicable*	*Not Applicable*	Difference between "Baro Altitude" and "GNSS Height (HAE)"	
	1 – 4				**Airborne Velocity Message** (§2.2.3.2.6)				
	5 – 7				Reserved				
20	Not Present	0	0	--	**Airborne Position Message** (§2.2.3.2.3)	$R_C < 7.5$ m	NIC = 11	GNSS Height (HAE)	2, 5
21		0	0	--		$R_C < 25$ m	NIC = 10		2, 5
22		0	0	--		$R_C \geq 25$ m or unknown	NIC = 0		2

Table 2-16: "TYPE" Subfield Code Definitions (DF=17 or 18) (Continued)

TYPE Code	Subtype Code	NIC Supplement	Format (Message Type)
23	0	*Not Applicable*	**Test Message** (§2.2.3.2.7.3)
	1 – 7		Reserved
24	0		Reserved
	1		**Surface System Status** (§2.2.3.2.7.4) (Allocated for National Use)
	2 – 7		Reserved
25 – 26			**Reserved** (§2.2.3.2.7.5 and §2.2.3.2.7.6)
27			**Reserved for Trajectory Change Message** (§2.2.3.2.7.7)
28	0		Reserved
	1		**Extended Squitter Aircraft Status Message (Emergency/Priority Status)** (§2.2.3.2.7.8.1)
	2		**Extended Squitter Aircraft Status Message (1090ES TCAS RA Message)** (§2.2.3.2.7.8.2)
	3 – 7		Reserved
29	0		Target State and Status Message (ADS-B Version Number=1, defined in RTCA DO-260A)
	1		**Target State and Status Message** (§2.2.3.2.7.1) (ADS-B Version Number=2, defined in these MOPS, RTCA DO-260B)
	2 – 3		Reserved
30	0 – 7		Reserved
31	0 – 1		**Aircraft Operational Status Message** (§2.2.3.2.7.2)
	2 – 7		Reserved

<u>Notes for Table 2-16:</u>

1. *"Baro Altitude" means barometric pressure altitude, relative to a standard pressure of 1013.25 millibars (29.92 in.Hg.). It does* **not** *mean baro corrected altitude.*

2. *TYPE codes 20 to 22 or TYPE Code 0 are to be used when valid "Baro Altitude" is not available.*

3. *After initialization, when horizontal position information is not available but altitude information is available, the Airborne Position Message is transmitted with a TYPE Code of ZERO in bits 1-5, the barometric pressure altitude in bits 9 to 20, and bits 22 to 56 set to ZERO (0). If neither horizontal position nor barometric altitude information is available, then all 56 bits of Register 05_{16} are set to zero. The ZERO (0) TYPE Code field indicates that latitude and longitude information is not available, while the Zero altitude field indicates that altitude information is not available. (See Appendix A).*

4. *If the position source is an ARINC 743A GNSS receiver, then the ARINC 429 data "label 130" data word from that receiver is a suitable source of information for R_C, the horizontal integrity containment radius. (The label 130 data word is variously called HPL (Horizontal Protection Limit) or HIL (Autonomous Horizontal Integrity Limit) in different documents.*

5. *This TYPE Code value implies limits for the R_C (horizontal containment limit). If this limit is not satisfied, then a different value for the TYPE Code should be selected.*

6. *The "NIC Supplement" field in the Airborne Position Message (§2.2.3.2.3.3) and in the Aircraft Operational Status Message (§2.2.3.2.7.2.6) enables the Report Assembly Function in ADS-B Receiving Subsystem to determine whether the ADS-B Transmitting Subsystem is announcing NIC=8 (R_C < 0.1 NM) or NIC=9 (R_C < 75 m).*

7. *The "NIC Supplement" field in the Airborne Position Message (§2.2.3.2.3.3) and in the Aircraft Operational Status Message (§2.2.3.2.7.2.6) enables the Report Assembly Function in ADS-B Receiving Subsystem to determine whether the ADS-B Transmitting Subsystem is announcing NIC=2 (R_C < 8 NM) or NIC=3 (R_C < 4 NM).*

8. *Future versions of these MOPS may limit transmission of Surface Position Messages at lower NIC and/or NAC_P values for Transponder-Based systems.*

2.2.3.2.3.1.1 Airborne Position Message TYPE Code if Radius of Containment is Available

<u>Note:</u> *If the position information comes from a GNSS receiver that conforms to the ARINC 743A characteristic, a suitable source of information for the radius of containment (R_C), is ARINC 429 label 130 from that GNSS receiver.*

If Radius of Containment (R_C) information is available from the navigation data source, then the ADS-B Transmitting Subsystem **shall** determine the TYPE Code (the value of the TYPE Code subfield) of Airborne Position Messages as follows.

a. If current valid horizontal position information is not available to the ADS-B Transmitting Subsystem, then the TYPE Code subfield of Airborne Position Messages **shall** be set to ZERO (0) as described in §2.2.3.2.3.1.3.2 below.

b. If valid horizontal position and barometric pressure altitude information are both available to the ADS-B Transmitting Subsystem, then the ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield of Airborne Position Messages to a value in the range from 9 to 18 in accordance with Table 2-16.

c. If valid horizontal position information is available to the ADS-B Transmitting Subsystem, but valid barometric pressure altitude information is ***not*** available, and valid geometric altitude information ***is*** available, the ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield of Airborne Position Messages to a value in the range from 20 to 22 depending on the radius of containment R_C in accordance with Table 2-16.

d. If valid horizontal position information is available to the ADS-B Transmitting Subsystem, but neither valid barometric altitude information nor valid geometric altitude information is available, the ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield in Airborne Position Messages to a value in the range from 9 to 18 depending on the radius of containment R_C in accordance with Table 2-16. (In that case, the ALTITUDE subfield of the Airborne Position Messages would be set to ALL ZEROs in accordance with §2.2.3.2.3.4.3 below, in order to indicate that valid altitude information is ***not*** available.)

2.2.3.2.3.1.2 Airborne Position Message TYPE Code if Radius of Containment is Not Available

If R_C (radius of containment) information is NOT available from the navigation data source, then the ADS-B Transmitting Subsystem **shall** indicate NIC=0 by selecting a TYPE Code of 0, 18, or 22 in the Airborne Position Messages, as follows:

a. The ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield to ZERO (0) if valid horizontal position information is ***not*** available, as described in §2.2.3.2.3.1.3.2 below.

b. The ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield to 18 if valid pressure altitude information ***is*** available, or if neither valid pressure altitude nor valid geometric altitude information is available.

If valid pressure altitude ***is not*** available, but valid geometric altitude information is available, the ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield to 22.

2.2.3.2.3.1.3 Special Processing for TYPE Code Equal to ZERO

2.2.3.2.3.1.3.1 Significance of TYPE Code Equal to ZERO

As shown in Table 2-16, TYPE Code equal to ZERO (0) is labeled “No Position Information.” This type of message is intended to be used when horizontal position information is not available or is invalid, and still permit the reporting of barometric altitude, when it is available and valid. As such, the principal use of this message case is to provide TCAS the ability to passively receive altitude information.

Airborne Position Messages may be transmitted with a TYPE Code of ZERO (0) under the following condition:

An Airborne Position Message with a TYPE Code of ZERO (0) **shall** set all 56 bits of the "ME" field bits to ZERO (0) if NO barometric pressure Altitude data is available. If valid pressure Altitude data is available, then the "Altitude" subfield, "ME" bits 9 - 20, Message bits 41 - 52, **shall** report the altitude in accordance with §2.2.3.2.3.4.3.

Note: *Special processing is required for Airborne Position Messages because a CPR encoded value of ALL ZEROs in the latitude and longitude field is considered to be a valid encoding.*

2.2.3.2.3.1.3.2 Broadcast of TYPE Code Equal to ZERO

The TYPE Code Equal to ZERO message may be required as a consequence of the following events:

a. An ADS-B Airborne Position or Surface Position Message register has not been loaded with data in the last 2 seconds. In this case, the ADS-B Message register **shall** be cleared (i.e., all 56 bits set to ZERO) once it has timed out. Transmission of the ADS-B Message that broadcasts the contents of the register **shall** be terminated if the ADS-B Message register has not been loaded in 60 seconds, except that transmission termination of Surface Position Messages does not apply to Non-Transponder-Based Devices on aircraft that are on the surface, on surface vehicles, or if barometric altitude information is available. Broadcast of the ADS-B Airborne Position or Surface Position Message **shall** resume once data has been loaded into the ADS-B Message register.

b. The data management function responsible for loading the ADS-B Message registers determines that all navigation sources that can be used for the Airborne or Surface Position Message are either missing or invalid. In this case the data management function **shall** clear (set all data fields to all ZEROs) the TYPE Code and all other fields of the Airborne or Surface Position Message and insert the ZEROed message into the appropriate ADS-B Message register. This should only be done once in support of the detection of the loss of data insertion and **shall** result in the suppression of the broadcast of the related ADS-B Message.

c. Note that in all of the cases discussed above, a TYPE Code of ZERO infers a message of ALL ZEROs. The only exception is that the Airborne Position Message format **shall** contain barometric altitude code as set by the transponder when so implemented. There is no analogous case for the other Extended Squitter Message Types, since a ZERO value in any of the fields indicates that no valid information is available.

2.2.3.2.3.1.4 TYPE Code based on Horizontal Position and Altitude Data

a. If valid horizontal position information is available, and valid pressure altitude information is available, then the "TYPE" Code in the Airborne Position Message **shall** be set in the range from "9" to "18."

b. If valid horizontal position information is available, valid pressure altitude is NOT available, and GNSS Height Above the Ellipsoid (HAE) data is available, then the

"TYPE" Code in the Airborne Position Message **shall** be set in the range from "20" to "22."

c. If valid horizontal position information is available, but neither valid pressure altitude information nor valid GNSS Height Above Ellipsoid (HAE) information is available, then the "TYPE Code in the Airborne Position Message **shall** be set in the range from "9" to "18."

d. In all three cases, "a," "b," and "c" above, the "TYPE" Coding **shall** be selected in accordance with the Radius of Containment (R_C) given in Table 2-16.

Alternatively, the "TYPE" Code may be selected in accordance with the Horizontal Protection Limits (HPL) given in Table 2-16.

2.2.3.2.3.2 "Surveillance Status" Subfield in ADS-B Airborne Position Messages

The "Surveillance Status" subfield is a 2-bit ("ME" bits 6 and 7, Message bits 38 and 39) field that **shall** be used to encode information from the aircraft's Mode-A transponder code as provided in Table 2-17.

Table 2-17: "Surveillance Status" Subfield Code Definitions

Coding (Binary)	Coding (Decimal)	Meaning
00	0	No Condition Information
01	1	Permanent Alert Condition (Emergency)
10	2	Temporary Alert Condition (change in Mode A Identity Code other than emergency condition)
11	3	Special Position Identification (SPI) Condition

Note: *Codes 1 and 2 take precedence over code 3.*

The setting of the "Surveillance Status" is a transponder function and is appropriately specified in RTCA DO-181D, §2.2.18.2.7 & §2.2.23.1.8 (EUROCAE ED-73C, §3.23.1.6 & §3.28.8).

When not implemented in a Mode-S Transponder-Based system, the ADS-B function **shall** set the "Surveillance Status" subfield to ZERO.

2.2.3.2.3.3 "NIC Supplement-B" Subfield in ADS-B Airborne Position Messages

The NIC Supplement-B subfield in the Airborne Position Message is a one-bit subfield ("ME" bit 8, Message bit 40) that, together with the TYPE Code subfield, **shall** be used to encode the Radius of Containment (R_C) and the Navigation Integrity Category (NIC) of the transmitting ADS-B participant. The NIC Supplement-A subfield is also broadcast in the Aircraft Operational Status Message (§2.2.3.2.7.2.6).

Note: *The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of integrity for the intended use. See §2.1.2.12 of RTCA DO-242A, the ADS-B MASPS, for a fuller description of the Navigation Integrity Category.*

If an update has not been received from an on-board data source for the determination of the NIC value within the past 5 seconds, then the NIC Supplement-B subfield **shall** be encoded to indicate the larger Radius of Containment (R_C).

Table 2-70 lists the possible NIC codes and the values of the TYPE Code subfield of the Airborne and Surface Position Messages, and of the NIC Supplement-A and NIC Supplement-B subfield that **shall** be used to encode those NIC codes in messages on the 1090 MHz ADS-B data link.

2.2.3.2.3.4 "Altitude" Subfield in ADS-B Airborne Position Messages

The "Altitude" subfield is a 12-bit ("ME" bit 9 through 20, Message bit 41 through 52) field that **shall** contain the altitude of the ADS-B Transmitting Subsystem as provided in the following subparagraphs.

2.2.3.2.3.4.1 "Barometric Altitude" in ADS-B Airborne Position Messages

Barometric Pressure Altitude relative to a standard pressure of 1013.25 millibars (29.92 in.Hg.) **shall** be reported in the "Altitude" Subfield of Airborne Position Messages having "TYPE" Codes 9 through 18 (see §2.2.3.2.3.1 and Table 2-16) under the following condition:

Barometric Pressure Altitude is selected for reporting via a control selection process and such Barometric Pressure Altitude data is valid.

Note: *"Barometric Pressure Altitude" specifically **DOES NOT** refer to "Barometric Corrected Altitude."*

Encoding of the Barometric Pressure Altitude data into the "Altitude" subfield **shall** be in accordance with §2.2.3.2.3.4.3.

2.2.3.2.3.4.2 "GNSS Height Above the Ellipsoid (HAE)" in ADS-B Airborne Position Messages

GNSS Height Above the Ellipsoid (HAE) **shall** be reported in the "Altitude" Subfield of the Airborne Position Message having "TYPE" Codes 20 through 22 (see §2.2.3.2.3.1 and Table 2-16) under the following condition:

> GNSS Height Above the Ellipsoid (HAE) is selected for reporting via a control selection process and such GNSS Height Above the Ellipsoid (HAE) data is valid.

Encoding of the GNSS Height Above the Ellipsoid (HAE) data into the "Altitude" subfield **shall** be in accordance with §2.2.3.2.3.4.3.

Note: *GNSS height may be useful for integrity checking of altitude and in future ATC concepts.*

2.2.3.2.3.4.3 "Altitude Encoding" in ADS-B Airborne Position Messages

Altitude data **shall** be encoded into the "Altitude" subfield as follows:

a. Bit 16 (i.e., Message bit 48) **shall** be designated as the **"Q"** bit. **"Q"** equals ZERO (0) **shall** be used to indicate that the Altitude is reported in 100 foot increments as specified in paragraph “b” below. **“Q”** equals ONE (1) **shall** be used to indicate that the altitude is reported in 25 foot increments as specified in paragraph “c” below.

b. If **“Q”** is equal to ZERO (0), then the Altitude **shall** be coded in 100 foot increments by selection of pulses in accordance with ICAO ANNEX 10, Volume IV, fourth edition, July 2007, Appendix 1 to Chapter 3, (see RTCA DO-181D, §2.2.13.1.2.a.(2).(c)) (EUROCAE ED-73C, §3.17.1.b.1.ii and 3.18.4.2). The appropriate mapping for the sequence of pulses **shall** be as shown in Figure 2-4.

Altitude Subfield Encoding for “Q” = “0”												
MSG BIT #	41	42	43	44	45	46	47	48	49	50	51	52
“ME” BIT #	9	10	11	12	13	14	15	16	17	18	19	20
CODE BIT	C1	A1	C2	A2	C4	A4	B1	“Q”	B2	D2	B4	D4

Figure 2-4: Altitude Subfield Encoding For “Q=0”

c. If **“Q”** is equal to ONE (1), then the Altitude **shall** be coded such that bits 9 through 15, and 17 to 20 (Message bits 41 through 47, and 49 through 52) represent a binary-coded field whose least significant bit has a value of 25 feet. The binary value of the decimal number “N” **shall** be used to report Pressure Altitudes in the range (25 * N - 1000 ± 12.5 feet).

The most significant bit of this field is bit 9. This code is able to provide code values only between -1000 feet and +50175 feet. The coding used for Altitudes that are greater than 50175 feet **shall** conform to the coding principles described in paragraph “b” above.

d. If altitude data is not available, then all bits of the Altitude subfield **shall** be set to ZERO.

Note: *These requirements are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.6.5.4, as well as with the requirements of RTCA DO-181D, §2.2.13.1.2 (EUROCAE ED-73C, §3.17.1.b).*

2.2.3.2.3.5 “TIME” (T) Subfield in ADS-B Airborne Position Messages

The “TIME” (T) subfield is a 1-bit (“ME” bit 21, Message bit 53) field that **shall** indicate whether or not the epoch of validity for the horizontal position data in an Airborne Position Message is an exact 0.2 second UTC epoch. If the time of applicability of the position data is synchronized to an exact 0.2 second UTC epoch, the “TIME” (T) subfield **shall** be set to “1;” otherwise, the “TIME” (T) subfield **shall** be set to ZERO (0).

Notes:

1. *An ADS-B Transmitting Subsystem that sets the "TIME" (T) subfield to ONE (1) must accept a GNSS TIME MARK input from the navigation data source in order to be able to update the position data from the navigation data source to an exact 0.2 second UTC epoch (See §2.2.5.1.6).*

2. *An arithmetic description of the intended synchronization implementation is provided in the **"Commentary"** paragraphs provided in §2.2.3.2.3.7.2 for precision Latitude Position Extrapolation and in §2.2.3.2.3.8.2 for precision Longitude Position Extrapolation.*

2.2.3.2.3.6 "CPR Format" (F) Subfield in ADS-B Airborne Position Messages

The "CPR Format" (F) subfield is a 1-bit ("ME" bit 22, Message bit 54) field that **shall** be used to indicate which Compact Position Reporting (CPR) Format type ("**even**" or "**odd**") is used to encode the latitude and longitude data (see §2.2.3.2.3.7 and §2.2.3.2.3.8). The bit **shall** be set to "ZERO" to indicate the "**even**" encoding of such data, or to "ONE" to indicate the "**odd**" encoding of such data.

a. When "TIME" (T) = 0:

The "CPR Format" (F) subfield functions ONLY to indicate the "**even**" or "**odd**" CPR encoding. In this case, the CPR encoding type **shall** alternate between "**even**" and "**odd**," and the "CPR Format" (F) subfield **shall** alternate between ZERO (0) and ONE (1) respectively, each time the Airborne Position Message register is updated with new position data.

Note: *When the "TIME" (T) subfield is "ZERO," the Airborne Position Message register must be updated at least as frequently as every 200 milliseconds: however, it may be updated more frequently, for example, every 100 milliseconds, etc. In such cases, the CPR encoding should alternate between "**even**" and "**odd**" each time that the register is updated with new position data.*

b. When "TIME" (T) = 1:

The "CPR Format" (F) subfield functions to indicate the "**even**" or "**odd**" CPR encoding and also indicates whether the epoch of applicability of the position data is an "**even**" or "**odd**" 0.2 second UTC epoch.

Notes:

1. *Although the Airborne Position Message register may be updated more frequently than five times per second, the "CPR Format" (F) subfield alternates between ZERO (0) and ONE (1) only as the epoch of applicability of the data being loaded into the register alternates between "**even**" and "**odd**" 0.2 second UTC epochs.*

2. *An "even 0.2 second UTC epoch" is defined as that moment on the UTC time scale that occurs at an even number of 200-millisecond intervals after an exact even-numbered UTC second. Likewise, an "odd 0.2 second UTC epoch" is defined as that moment on the UTC time scale that occurs at an odd number of 200 millisecond intervals after an even numbered UTC second. Examples of even 0.2 second epochs are 12.0 seconds, 12.4 seconds, 12.8 seconds, 13.2 seconds, 13.6 seconds, etc. Examples of odd 0.2 second epochs are 12.2 seconds, 12.6 seconds, 13.0 seconds, 13.4 seconds, 13.8 seconds, etc.*

2.2.3.2.3.7 "CPR Encoded Latitude" Subfield in ADS-B Airborne Position Messages

The "CPR Encoded Latitude" subfield is a 17-bit ("ME" bit 23 through 39, Message bit 55 through 71) field containing the CPR encoded latitude of the airborne position.

2.2.3.2.3.7.1 Airborne Latitude Data Encoding

The airborne latitude position data **shall** be encoded in accordance with §A.1.4.2.2 and §A.1.7 of Appendix A.

2.2.3.2.3.7.2 Airborne Latitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 9, 10, 20 and 21)

The following subsections apply to Airborne Position Messages in which the TYPE Code is 9, 10, 20 and 21 (see §2.2.3.2.3.1).

2.2.3.2.3.7.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1")

If "TIME" (T) = 1 (see §2.2.3.2.3.5) in an Airborne Position Message, then the time of applicability of the latitude and longitude fields in that message **shall** be an exact 0.2 second UTC epoch.

a. Specifically, the position data in the latitude and longitude fields **shall** be extrapolated forward from the time of validity of the position fix to the time of applicability of the Airborne Position Message.

b. The Airborne latitude data registers and the encoded latitude subfield **shall** be updated every 200 milliseconds to the next 0.2 UTC Epoch using the velocity data provided for the position fix.

<u>Notes:</u>

1. *The time of validity of the fix is provided with the fix data from the navigation data source and is indicated by the leading edge of the GNSS Time Mark (see §2.2.5.1.6). The time of applicability of the position message is the exact 0.2 second UTC Epoch to which the position data is extrapolated.*

2. *The latitude position registers and encoded latitude subfield should be updated at a time about 100 milliseconds before the time of applicability of the data being loaded into that register (see §2.2.5.2.1 and Appendix A, §A.1.4.2.3.1).*

3. *One method of estimating the position to an exact 0.2 second UTC Epoch is described in the following "Commentary."*

COMMENTARY:

The following example provides one method (not the only method) that latitude given in the Airborne Position Message may be extrapolated from the time of validity of the fix (included with the fix from the navigation data source) to the time of applicability of the Airborne Position Message. In the example, it is assumed that the "TIME" (T) subfield (see §2.2.3.2.3.5) is "ONE," indicating that the time of applicability of the extrapolated position is an exact 0.2 second UTC Epoch.

Let:

t_{fix}	=	*time of the leading edge of the last received GNSS Time Mark (see §2.2.5.1.6), which is also the time of validity included with the fix from the navigation data source.*
$t_{message}$	=	*time of applicability of the Airborne Position Message, which is an exact 0.2 second UTC Epoch.*
Δt	=	$t_{message} - t_{fix}$*, in milliseconds*
ϕ_{fix}	=	*last known latitude position, at time* t_{fix}*, in degrees*
$\phi_{message}$	=	*latitude, extrapolated forward to the time of applicability of the Airborne Position Message,* $t_{message}$
$\Delta\phi$	=	$\phi_{message} - \phi_{fix}$*, in degrees*
v_{NS}	=	*North/South Velocity*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\phi_{message} = \phi_{fix} + \Delta\phi$$

$$= \phi_{fix} + (v_{NS}/60)(\Delta t/3600000)$$

$$= \phi_{fix} + (v_{NS}\,\Delta t) / (2.16 \times 10^{8})$$

(We divide v_{NS} *by 60 to convert from knots in the N-S direction to degrees of latitude per hour, and divide* Δt *by 3600 x 1000 to convert from milliseconds to hours.)*

The result, $\phi_{message}$*, is to be encoded in the latitude field of the Airborne Position Message using the CPR algorithm described in Appendix A, §A.1.7.*

2.2.3.2.3.7.2.2 Non-Coupled Case (Estimation, "TIME" (T) = "0")

ADS-B Airborne Position Messages with TYPE Codes of 9, 10, 20 and 21 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.3.7.2.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the airborne latitude data registers and encoded latitude data subfield at intervals not to exceed 100 milliseconds

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.3.7.2.1 is not degraded.*

2.2.3.2.3.7.3 Airborne Latitude Position Extrapolation/Estimation (non - precision)

2.2.3.2.3.7.3.1 Airborne Latitude Position Extrapolation Case (non - precision)

ADS-B Airborne Position Messages with TYPE Codes other than 9, 10, 20 or 21 (see §2.2.3.2.3.1) **shall** contain an estimate of the latitude position at a time of applicability that is within 200 milliseconds of the time that the Airborne Position Message is transmitted. Essentially, the original data and the encoded latitude **shall** be updated at least as frequently as every 200 milliseconds.

COMMENTARY:

The only difference between latitude position extrapolation in the non-precision case and that of the precision case (§2.2.3.2.3.7.2.1) is the interpretation of what "Δt" means. In the non-precision case, Δt is the elapsed time from the last received position update to the expected time of transmission of an Airborne Position Message that is based on the last position update.

(In the precision case, Δt is the time interval from the last received leading edge of the GNSS Time Mark to the 0.2 second UTC Epoch which is to be the time of applicability of the Airborne Position Message).

Let:

t_{fix}	=	*time validity included with the PVT (position, velocity, time) data from the navigation data source.*
t_{update}	=	*time when the transmitting ADS-B Subsystem receives the most recent PVT (position, velocity, time) data from a navigation data source.*
$t_{message}$	=	*time of applicability of the Airborne Position Message*
Δt	=	$t_{message} - t_{update}$*, in milliseconds*
ϕ_{fix}	=	*last known latitude position, at time* t_{fix}*, in degrees*
$\phi_{message}$	=	*latitude, extrapolated forward to the time of applicability of the Airborne Position Message,* $t_{message}$
$\Delta\phi$	=	$\phi_{message} - \phi_{fix}$*, in degrees*
v_{NS}	=	*North/South Velocity*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\phi_{message} = \phi_{fix} + \Delta\phi$$

$$= \phi_{fix} + (v_{NS}/60)(\Delta_t/3600000)$$

$$= \phi_{fix} + (v_{NS}\ \Delta_t) / (2.16 \times 10^8)$$

(We divide v_{NS} by 60 to convert from knots in the N-S direction to degrees of latitude per hour, and divide Δ_t by 3600 x 1000 to convert from milliseconds to hours.)

The result, $\phi_{message}$, is to be encoded in the latitude field of the Airborne Position Message using the CPR algorithm described in Appendix A, §A.1.7.

Note: *In order not to introduce excessive error in the estimated latitude, $\phi_{message}$, the latency, t_{update} - t_{fix}, in the delivery of PVT data from the navigation data source should not be excessive.*

2.2.3.2.3.7.3.2 Airborne Latitude Position Estimation Case (non - precision)

ADS-B Airborne Position Messages with TYPE Codes other than 9, 10, 20 and 21 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.3.7.3.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the airborne latitude data registers and encoded latitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.3.7.3.1 is not degraded.*

2.2.3.2.3.7.4 Airborne Latitude Position Data Retention

In the event that the latitude position data is no longer available, the extrapolation or estimation of, and update of latitude data and fields specified in §2.2.3.2.3.7.2 through §2.2.3.2.3.7.3.2 **shall** be limited to no more than two seconds.

At the end of two seconds, the latitude data registers and the encoded latitude field **shall** be set to ALL ZEROs.

2.2.3.2.3.8 "CPR Encoded Longitude" Subfield in ADS-B Airborne Position Messages

The "CPR Encoded Longitude" subfield is a 17-bit ("ME" bit 40 through 56, Message bit 72 through 88) field that **shall** contain the encoded longitude of the airborne position.

2.2.3.2.3.8.1 Airborne Longitude Data Encoding

The airborne longitude position data **shall** be encoded in accordance with §A.1.4.2.2 and §A.1.7 of Appendix A.

2.2.3.2.3.8.2 Airborne Longitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 9, 10, 20 and 21)

2.2.3.2.3.8.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1")

If "TIME" (T) = 1 (see §2.2.3.2.3.5) in an Airborne Position Message, then the time of applicability of the latitude and longitude fields in that message **shall** be an exact 0.2 second UTC epoch.

a. Specifically, the position data in the latitude and longitude fields **shall** be extrapolated forward from the time of validity of the position fix to the time of applicability of the Airborne Position Message.

b. The Airborne longitude data registers and the encoded longitude subfield **shall** be updated every 200 milliseconds to the next 0.2 UTC Epoch using the velocity data provided for the position fix.

Notes:

1. *The time of validity of the fix is provided with the fix data from the navigation data source and is indicated by the leading edge of the GNSS Time Mark (see §2.2.5.1.6). The time of applicability of the position message is the exact 0.2 second UTC Epoch to which the position data is extrapolated.*

2. *The longitude position registers and encoded longitude subfield should be updated at a time about 100 milliseconds before the time of applicability of the data being loaded into that register (see §2.2.5.2.1 and Appendix A, §A.1.4.2.3.1).*

3. *One method of estimating the position to an exact 0.2 second UTC Epoch is described in the following "Commentary."*

COMMENTARY:

The following example provides one method (not the only method) that longitude given in the Airborne Position Message may be extrapolated from the time of validity of the fix (included with the fix from the navigation data source) to the time of applicability of the Airborne Position Message. In the example, it is assumed that the "TIME" subfield (see §2.2.3.2.3.5) is "ONE," indicating that the time of applicability of the extrapolated position is an exact 0.2 second UTC Epoch.

Let:

t_{fix}	=	*time of the leading edge of the last received GNSS Time Mark (see §2.2.5.1.6), which is also the time of validity included with the fix from the navigation data source.*
$t_{message}$	=	*time of applicability of the Airborne Position Message, which is an exact 0.2 second UTC Epoch.*
Δt	=	$t_{message} - t_{fix}$*, in milliseconds*
λ_{fix}	=	*last known longitude position, at time* t_{fix}*, in degrees*
$\lambda_{message}$	=	*longitude, extrapolated forward to the time of applicability of the Airborne Position Message,* $t_{message}$
$\Delta\lambda$	=	$\lambda_{message} - \lambda_{fix}$*, in degrees*
ϕ	=	*approximate latitude (the latitude,* ϕ_{fix}*, at the time of the fix may be used)*
v_{EW}	=	*last known E-W velocity at time* t_{fix}*, in knots (positive for easterly velocity)*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\lambda_{message} = \lambda_{fix} + \Delta\lambda$$

$$= \lambda_{fix} + [(v_{EW})/(60 \cos(\phi))] (\Delta t/3600000)$$

$$= \lambda_{fix} + (v_{EW}\,\Delta t) / [(2.16 \times 10^8) \cos(\phi)]$$

(We divide v_{EW} by *60 cos* (ϕ) *to convert from knots in the E-W direction to degrees of longitude per hour, and divide* Δt *by 3600 x 1000 to convert from milliseconds to hours.)*

The result, $\lambda_{message}$*, is to be encoded in the longitude field of the Airborne Position Message using the CPR algorithm described in Appendix A, §A.1.7.*

2.2.3.2.3.8.2.2 Non-Coupled Case (Estimation, "TIME" (T) = "0")

ADS-B Airborne Position Messages with TYPE Codes of 9, 10, 20 and 21 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.3.8.2.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the airborne longitude data registers and encoded longitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.3.8.2.1 is not degraded.*

2.2.3.2.3.8.3 Airborne Longitude Position Extrapolation/Estimation (non - precision)

2.2.3.2.3.8.3.1 Airborne Longitude Position Extrapolation Case (non - precision)

ADS-B Airborne Position Messages with TYPE Codes other than 9, 10, 20 or 21 (see §2.2.3.2.3.1) **shall** contain an estimate of the longitude position at a time of applicability that is within 200 milliseconds of the time that the Airborne Position Message is transmitted. Essentially, the original data and the encoded longitude **shall** be updated at least as frequently as every 200 milliseconds.

COMMENTARY:

The only difference between longitude position extrapolation in the non-precision case and that of the precision case (§2.2.3.2.3.7.2.1) is the interpretation of what "Δt" means. In the non-precision case, Δt is the elapsed time from the last received position update to the expected time of transmission of an Airborne Position Message that is based on the last position update. (In the precision case, Δt is the time interval from the last received leading edge of the GNSS Time Mark to the 0.2 second UTC Epoch which is to be the time of applicability of the Airborne Position Message).

Let:

t_{fix}	=	*time validity included with the PVT (position, velocity, time) data from the navigation data source.*
t_{update}	=	*time when the transmitting ADS-B Subsystem receives the most recent PVT (position, velocity, time) data from a navigation data source.*
$t_{message}$	=	*time of applicability of the Airborne Position Message*
Δt	=	$t_{message} - t_{update}$, *in milliseconds*
λ_{fix}	=	*last known longitude position, at time t_{fix}, in degrees*
$\lambda_{message}$	=	*longitude, extrapolated forward to the time of applicability of the Airborne Position Message, $t_{message}$*
$\Delta\lambda$	=	$\lambda_{message} - \lambda_{fix}$, *in degrees*
ϕ	=	*approximate latitude (the latitude, ϕ_{fix}, at the time of the fix may be used)*
v_{EW}	=	*last known E-W velocity at time t_{fix}, in knots (positive for easterly velocity)*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\lambda_{message} = \lambda_{fix} + \Delta\lambda$$

$$= \lambda_{fix} + [(v_{EW})/(60 \cos(\phi))]\ (\Delta t/3600000)$$

$$= \lambda_{fix} + (v_{EW}\ \Delta t) / [(2.16 \times 10^{8}) \cos(\phi)]$$

(We divide v_{EW} by *60 cos (*ϕ*) to convert from knots in the E-W direction to degrees of longitude per hour, and divide* Δt *by 3600 x 1000 to convert from milliseconds to hours.)*

The result, $\lambda_{message}$*, is to be encoded in the longitude field of the Airborne Position Message using the CPR algorithm described in Appendix A, §A.1.7.*

Note: *In order not to introduce excessive error in the estimated longitude,* $\lambda_{message}$*, the latency,* t_{update} - t_{fix}*, in the delivery of PVT data from the navigation data source should not be excessive.*

2.2.3.2.3.8.3.2 Airborne Longitude Position Estimation Case (non - precision)

ADS-B Airborne Position Messages with TYPE Codes other than 9, 10, 20 and 21 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.3.8.3.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the airborne longitude data registers and encoded longitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.3.8.3.1 is not degraded.*

2.2.3.2.3.8.4 Airborne Longitude Position Data Retention

The extrapolation or estimation, and update of longitude data and fields specified in §2.2.3.2.3.8.2 through §2.2.3.2.3.8.3.2 **shall** be limited to no more than two seconds, in the event that the longitude position data is no longer available.

At the end of two seconds, the longitude data registers and the encoded longitude field **shall** be set to ALL ZEROs.

2.2.3.2.4 ADS-B Surface Position Messages

The format for the Surface Position Message "ME" field contents is specified in Figure 2-5. Each of the subfields is specified in the following subparagraphs.

Surface Position Message "ME" Field								
Msg Bit #	33 - 37	38 - 44	45	46 - 52	53	54	55 - 71	72 - 88
"ME" Bit #	1 - 5	6 - 12	13	14 - 20	21	22	23 - 39	40 – 56
Field Name	**TYPE Code [5]**	**Movement [7]**	**Heading/ Ground Track Status [1]**	**Heading/ Ground Track [7]**	**Time (T) [1]**	**CPR Format (F) [1]**	**CPR Encoded Latitude [17]**	**CPR Encoded Longitude [17]**
	MSB LSB	MSB LSB		MSB LSB			MSB LSB	MSB LSB

Note: *"[#]" provided in the Field indicates the number of bits in the field.*

Figure 2-5: ADS-B Surface Position Message Format

2.2.3.2.4.1 "TYPE" Code Subfield in ADS-B Surface Position Messages

The "TYPE" Code subfield was previously specified for the Airborne Position Message in §2.2.3.2.3.1 and remains the same for the ADS-B Surface Position Message, which **shall** use TYPE Codes 5, 6, 7 and 8 only.

Detailed definition of the "TYPE" Code subfield encodings that **shall** be used for all ADS-B Messages are provided in Table 2-16.

2.2.3.2.4.1.1 Surface Position Message TYPE Code if Radius of Containment is Available

If R_C (horizontal radius of containment) information is available from the navigation data source, then the ADS-B Transmitting Subsystem **shall** use R_C to determine the TYPE Code used in the Surface Position Message in accordance with Table 2-16.

Note: *If the position information comes from a GNSS receiver that conforms to the ARINC 743A characteristic, a suitable source of information for the radius of containment (R_C), is ARINC 429 label 130 from that GNSS receiver.*

2.2.3.2.4.1.2 Surface Position Message TYPE Code if Radius of Containment is Not Available

If R_C (horizontal radius of containment) information is NOT available from the navigation data source, then the ADS-B Transmitting Subsystem **shall** indicate NIC=0 by selecting a TYPE Code of 0 or 8 in the Surface Position Messages, as follows:

a. The ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield to ZERO if valid horizontal position information is NOT available, as described in §2.2.3.2.3.1.3.2 above.

b. The ADS-B Transmitting Subsystem **shall** set the TYPE Code subfield to 8 if valid horizontal position information IS available. (This TYPE Code indicates that radius of containment, R_C, is either unknown or greater than or equal to 0.1 NM.) ➔ THIS NEED TO BE CHANGED WITH THE ADDITION OF THE NIC SUPPLEMENT-C AND THE NEW VALUES FOR R_C ON THE SURFACE 🡐

2.2.3.2.4.1.3 Special Processing for TYPE Code Equal to ZERO

2.2.3.2.4.1.3.1 Significance of TYPE Code Equal to ZERO

As shown in Table 2-16, TYPE Code equal to ZERO (0) is labeled "No Position Information." This type of message is intended to be used when the latitude and/or longitude information is not available, or is invalid.

A Surface Position Message with a TYPE Code eaual to ZERO (0) **shall** have all 56 bits of the "ME" field set to ZERO.

Special processing is required for Surface Position Messages because a CPR encoded value of ALL ZEROs in the latitude and longitude field is considered to be a valid encoding.

2.2.3.2.4.1.3.2 Broadcast of TYPE Code Equal to ZERO

The requirements provided in §2.2.3.2.3.1.3.2 apply equally to the ADS-B Surface Position Message except that subparagraph "c" is modified to read as follows:

c. Note that in all of the cases, a TYPE Code equal to ZERO infers a message of ALL ZEROs.

2.2.3.2.4.1.4 TYPE Code based on Horizontal Protection Level or Estimated Horizontal Position Accuracy

a. If valid horizontal position information is available, then the "TYPE" Code in the Surface Position Message **shall** be set in the range from "5" to "8."

b. If R_C (Horizontal Radius of Containment) information is available from the navigation data source, the "TYPE" Coding **shall** be selected according to the R_C value, in accordance with Table 2-16.

c. If R_C is not available from the navigation data source, then the "TYPE" Code **shall** be set to 8.

2.2.3.2.4.2 "Movement" Subfield in ADS-B Surface Position Messages

The "Movement " subfield is a 7-bit ("ME" bits 6 through 12, Message bits 38 through 44) field that **shall** be used to encode information regarding the status of "Movement" of the ADS-B Transmitting Subsystem in accordance with the coding provided in Table 2-18.

Table 2-18: "Movement" Subfield Code Definitions

Coding (Decimal)	Meaning	Quantization
0	No Movement Information Available	
1	Aircraft Stopped (Ground Speed = 0 knots)	
2	0 knots < Ground Speed ≤ 0.2315 km/h (0.125 kt)	
3 - 8	0.2315 km/h (0.125 kt) < Ground Speed ≤ 1.852 km/h (1 kt)	0.2700833 km/h steps
9 - 12	1.852 km/h (1 kt) < Ground Speed ≤ 3.704 km/h (2 kt)	0.463 km /h (0.25 kt) steps
13 - 38	3.704 km/h (2 kt) < Ground Speed ≤ 27.78 km/h (15 kt)	0.926 km/h (0.50 kt) steps
39 - 93	27.78 km/h (15 kt) < Ground Speed ≤ 129.64 km/h (70 kt)	1.852 km/h (1.00 kt) steps
94 - 108	129.64 km/h (70 kt) < Ground Speed ≤ 185.2 km/h (100 kt)	3.704 km/h (2.00 kt) steps
109 - 123	185.2 km/h (100 kt) < Ground Speed ≤ 324.1 km/h (175 kt)	9.26 km/h (5.00 kt) steps
124	324.1 km/h (175 kt) < Ground Speed	
125	Reserved for Aircraft Decelerating	
126	Reserved for Aircraft Accelerating	
127	Reserved for Aircraft Backing-Up	

Notes:

1. *The data encoding represented in Table 2-18 represents a non-linear encoding: therefore, encoding is performed exactly as specified in the table.*

2. *The last three movement encodings (125, 126, 127) are reserved to indicate high levels of ground speed change, etc. The precedence of the codes is not defined yet as inputs that would be required are not currently available.*

2.2.3.2.4.3 "Status Bit for Heading/Ground Track" Subfield in ADS-B Surface Position Messages

The "Status Bit for Heading/Ground Track" subfield is a 1-bit ("ME" bit 13, Message bit 45) field that **shall** be used to indicate the validity of the Heading or Ground Track as specified in Table 2-19.

Table 2-19: "Status Bit for Heading/Ground Track" Encoding

Coding	Meaning
0	Heading/Ground Track data is NOT VALID
1	Heading/Ground Track data is VALID

Note: *If a source of A/V Heading **is not** available to the ADS-B Transmitting Subsystem, but a source of Ground Track angle **is** available, then Ground Track angle may be used instead of Heading, provided that the "Status Bit for Heading/Ground Track" subfield is set to ZERO whenever the Ground Track angle is not a reliable indication of the A/V's heading. (The Ground Track angle is not a reliable indication of the A/V's heading when the A/V's ground speed is close to ZERO.)*

2.2.3.2.4.4 "Heading/Ground Track" Subfield in ADS-B Surface Position Messages

The "Heading/Ground Track" Subfield is a 7-bit ("ME" bit 14 through 20, Message Bit 46 through 52) field that **shall** be used to report the Heading, or motion of the ADS-B Transmitting Subsystem, Clockwise from North (i.e., Heading Sign Bit = 0). Encoding of the "Heading/Ground Track" Subfield is specified in Table 2-20.

Table 2-20: "Heading/Ground Track" Encoding

Coding (Binary)	Coding (Decimal)	Meaning (Heading/Ground Track in degrees)
000 0000	0	Heading/Ground Track is ZERO
000 0001	1	Heading/Ground Track = 2.8125 degrees
000 0010	2	Heading/Ground Track = 5.6250 degrees
000 0011	3	Heading/Ground Track = 8.4375 degrees
***	***	***
011 1111	63	Heading/Ground Track = 177.1875 degrees
100 0000	64	Heading/Ground Track = 180.00 degrees
100 0001	65	Heading/Ground Track = 182.8125 degrees
***	***	***
111 1111	127	Heading/Ground Track = 357.1875 degrees

Notes:

1. *The encoding shown in the table represents an Angular Weighted Binary encoding in degrees clockwise from True or Magnetic North. The MSB represents a bit weighting of 180 degrees, while the LSB represents a bit weighting of 360/128 degrees.*

2. *Raw data used to establish the Heading or Ground Track subfield will normally have more resolution (i.e., more bits) than that required by the Heading/Ground Track Subfield. When converting such data to the Heading/Ground Track Subfield, the accuracy of the data must be maintained such that it is not worse than ±½ LSB where the LSB is the weight of the least significant bit of the Heading subfield.*

3. *The reference direction for Heading (whether True North or Magnetic North) is indicated in the Horizontal Reference Direction (HRD) field of the Aircraft Operational Status Message (§2.2.3.2.7.2.13).*

2.2.3.2.4.5 "TIME" (T) Subfield in ADS-B Surface Position Messages

The "TIME" (T) subfield is a 1-bit ("ME" bit 21, Message bit 53) field that **shall** be used to indicate whether or not the epoch of validity for the horizontal position data in a Surface Position Message is an exact 0.2 second UTC epoch. If the time of applicability of the position data is synchronized to an exact 0.2 second UTC epoch, the "TIME" (T) subfield **shall** be set to ONE (1); otherwise, the "TIME" (T) subfield **shall** be set to ZERO (0).

The "TIME" (T) subfield may be set to ONE (1) only for TYPE Codes 5 and 6 (see §2.2.3.2.3.1 and Table 2-16) when used to indicated synchronization as discussed in the previous paragraph.

Notes:

1. *An ADS-B Transmitting Subsystem that sets the "TIME" (T) subfield to ONE (1) must accept a GNSS TIME MARK input from the navigation data source in order to be able to update the position data from the navigation data source to an exact 0.2 second UTC epoch (see §2.2.5.1.6).*

2. *An arithmetic description of the intended synchronization implementation is provided in the "Commentary" paragraphs provided in §2.2.3.2.4.7.2 for precision Latitude Position Extrapolation and in §2.2.3.2.4.8.2 for precision Longitude Position Extrapolation.*

2.2.3.2.4.6 "CPR Format" (F) Subfield in ADS-B Surface Position Messages

The "CPR Format" (F) subfield is a 1-bit ("ME" bit 22, Message bit 54) field that **shall** be used to indicate which Compact Position Reporting (CPR) format type ("**even**" or "**odd**") is used to encode the latitude and longitude data (see §2.2.3.2.4.7 and §2.2.3.2.4.8). The bit **shall** be set to "ZERO" to indicate the "**even**" encoding of such data, or to "ONE" to indicate the "**odd**" encoding of such data.

a. When "TIME" (T) = 0:

   The "CPR Format" (F) subfield functions ONLY to indicate the "**even**" or "**odd**" CPR encoding. In this case, the CPR encoding type **shall** alternate between "**even**" and "**odd**," and the "CPR Format" (F)" subfield **shall** alternate between ZERO (0) and ONE (1) respectively, each time the Surface Position Message register is updated with new position data.

   Note: *When the "TIME" (T) subfield is "ZERO," the Surface Position Message register must be updated at least as frequently as every 200 milliseconds: however, it may be updated more frequently, for example, every 100 milliseconds, etc. In such cases, the CPR encoding should alternate between "**even**" and "**odd**" each time that the register is updated with new position data.*

b. When "TIME" (T) = 1:

   The "CPR Format" (F) subfield functions to indicate the "**even**" or "**odd**" CPR encoding and also indicates whether the epoch of applicability of the position data is an "**even**" or "**odd**" 0.2 second UTC epoch.

Notes:

1. *Although the Surface Position Message register may be updated more frequently than five times per second, when T=1, the "CPR Format" (F) subfield alternates between ZERO (0) and ONE (1) only as the epoch of applicability of the data being loaded into the register alternates between "**even**" and "**odd**" 0.2 second UTC epochs.*

2. *An "even 0.2 second UTC epoch" is defined as that moment on the UTC time scale that occurs at an even number of 200-millisecond intervals after an exact even-numbered UTC second. Likewise, an "odd 0.2 second UTC epoch" is defined as that moment on the UTC time scale that occurs at an odd number of 200 millisecond intervals after an even numbered UTC second. Examples of even 0.2 second epochs are 12.0 seconds, 12.4 seconds, 12.8 seconds, 13.2 seconds, 13.6 seconds, etc. Examples of odd 0.2 second epochs are 12.2 seconds, 12.6 seconds, 13.0 seconds, 13.4 seconds, 13.8 seconds, etc.*

2.2.3.2.4.7 "CPR Encoded Latitude" Subfield in ADS-B Surface Position Messages

The "CPR Encoded Latitude" subfield is a 17-bit ("ME" bit 23 through 39, Message bit 55 through 71) field that **shall** contain the encoded latitude of the Surface position.

2.2.3.2.4.7.1 Surface Latitude Data Encoding

The surface latitude position data **shall** be encoded in accordance with §A.1.4.2.2 and §A.1.7 of Appendix A.

2.2.3.2.4.7.2 Surface Latitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 5 and 6)

The following subsections apply to Surface Position Messages with TYPE Codes of 5 and 6 (see §2.2.3.2.3.1).

2.2.3.2.4.7.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1")

If "TIME" (T) = 1 (see §2.2.3.2.3.5) in a Surface Position Message, then the time of applicability of the latitude and longitude fields in that message **shall** be an exact 0.2 second UTC epoch.

a. Specifically, the position data in the latitude and longitude fields **shall** be extrapolated forward from the time of validity of the position fix to the time of applicability of the Surface Position Message.

b. The Surface latitude data registers and the encoded latitude subfield **shall** be updated every 200 milliseconds to the next 0.2 UTC Epoch using the velocity data provided for the position fix.

<u>Notes:</u>

1. *The time of validity of the fix is provided with the fix data from the navigation data source and is indicated by the leading edge of the GNSS Time Mark (see §2.2.5.1.6). The time of applicability of the position message is the exact 0.2 second UTC Epoch to which the position data is extrapolated.*

2. *The latitude position registers and encoded latitude subfield should be updated at a time about 100 milliseconds before the time of applicability of the data being loaded into that register (see §2.2.5.2.1 and Appendix A, §A.1.4.2.3.1).*

3. *One method of estimating the position to an exact 0.2 second UTC Epoch is described in the following "Commentary."*

COMMENTARY:

The following example provides one method (not the only method) that latitude given in the Surface Position Message may be extrapolated from the time of validity of the fix (included with the fix from the navigation data source) to the time of applicability of the Surface Position Message. In the example, it is assumed that the "TIME" (T) subfield (see §2.2.3.2.3.5) is "ONE," indicating that the time of applicability of the extrapolated position is an exact 0.2 second UTC Epoch.

Let:

t_{fix}	=	*time of the leading edge of the last received GNSS Time Mark (see §2.2.5.1.6), which is also the time of validity included with the fix from the navigation data source.*
$t_{message}$	=	*time of applicability of the Surface Position Message, which is an exact 0.2 second UTC Epoch.*
Δt	=	$t_{message} - t_{fix}$, *in milliseconds*
ϕ_{fix}	=	*last known latitude position, at time* t_{fix}, *in degrees*
$\phi_{message}$	=	*latitude, extrapolated forward to the time of applicability the Surface Position Message,* $t_{message}$
$\Delta\phi$	=	$\phi_{message} - \phi_{fix}$, *in degrees*
v_{NS}	=	*North/South Velocity*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\phi_{message} = \phi_{fix} + \Delta\phi$$
$$= \phi_{fix} + (v_{NS}/60)(\Delta t / 3600000)$$
$$= \phi_{fix} + (v_{NS}\,\Delta t) / (2.16 \times 10^{8})$$

(We divide v_{NS} *by 60 to convert from knots in the N-S direction to degrees of latitude per hour, and divide* Δt *by 3600 x 1000 to convert from milliseconds to hours.)*

The result, $\phi_{message}$, *is to be encoded in the latitude field of the Surface Position Message using the CPR algorithm described in Appendix A, §A.1.7.*

2.2.3.2.4.7.2.2 Non-Coupled Case (Estimation, "TIME" (T) = "0")

ADS-B Surface Position Messages corresponding to precision categories 5 and 6 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.4.7.2.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the surface latitude data registers and encoded latitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.4.7.2.1 is not degraded.*

2.2.3.2.4.7.3 Surface Latitude Position Extrapolation/Estimation (non - precision)

2.2.3.2.4.7.3.1 Surface Latitude Position Extrapolation Case (non - precision)

ADS-B Surface Position Messages with TYPE Codes other than 5 or 6 (see §2.2.3.2.3.1) **shall** contain an estimate of the latitude position at a time of applicability that is within 200 milliseconds of the time that the Surface Position Message is transmitted. Essentially, the original data and the encoded latitude **shall** be updated at least as frequently as every 200 milliseconds.

COMMENTARY:

The only difference between latitude position extrapolation in the non-precision case and that of the precision case (§2.2.3.2.4.7.2.1) is the interpretation of what "Δt" means. In the non-precision case, Δt is the elapsed time from the last received position update to the expected time of transmission of a Surface Position Message that is based on the last position update.

(In the precision case, Δt is the time interval from the last received leading edge of the GNSS Time Mark to the 0.2 second UTC Epoch which is to be the time of applicability of the Surface Position Message).

Let:

t_{fix}	=	*time validity included with the PVT (position, velocity, time) data from the navigation data source.*
t_{update}	=	*time when the transmitting ADS-B Subsystem receives the most recent PVT (position, velocity, time) data from a navigation data source.*
$t_{message}$	=	*time of applicability of the Surface Position Message*
Δt	=	$t_{message} - t_{update}$*, in milliseconds*
ϕ_{fix}	=	*last known latitude position, at time* t_{fix}*, in degrees*
$\phi_{message}$	=	*latitude, extrapolated forward to the time of applicability of the Surface Position Message,* $t_{message}$
$\Delta\phi$	=	$\phi_{message} - \phi_{fix}$*, in degrees*
v_{NS}	=	*North/South Velocity*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\phi_{message} = \phi_{fix} + \Delta\phi$$
$$= \phi_{fix} + (v_{NS}/60)(\Delta_t/3600000)$$
$$= \phi_{fix} + (v_{NS}\,\Delta_t) / (2.16 \times 10^8)$$

(We divide v_{NS} by 60 to convert from knots in the N-S direction to degrees of latitude per hour, and divide Δ_t by 3600 x 1000 to convert from milliseconds to hours.)

The result, $\phi_{message}$, is to be encoded in the latitude field of the Surface Position Message using the CPR algorithm described in Appendix A, §A.1.7.

Note: *In order not to introduce excessive error in the estimated latitude, $\phi_{message}$, the latency, $t_{update} - t_{fix}$, in the delivery of PVT data from the navigation data source should not be excessive.*

2.2.3.2.4.7.3.2 Surface Latitude Position Estimation Case (non - precision)

ADS-B Airborne Position Messages that do not correspond to precision categories 5 and 6 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.4.7.3.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the surface latitude data registers and encoded latitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.4.7.3.1 is not degraded.*

2.2.3.2.4.7.4 Surface Latitude Position Data Retention

The extrapolation and update of latitude data and fields specified in §2.2.3.2.4.7.2 through §2.2.3.2.4.7.3.2 **shall** be limited to no more than two seconds, in the event that the latitude position data is no longer available. At the end of two seconds, the latitude data registers and the encoded latitude field **shall** be set to ALL ZEROs.

2.2.3.2.4.8 "CPR Encoded Longitude" Subfield in ADS-B Surface Position Messages

The "CPR Encoded Longitude" subfield is a 17-bit ("ME" bit 40 through 56, Message bit 72 through 88) field that **shall** contain the encoded longitude of the Surface position.

2.2.3.2.4.8.1 Surface Longitude Data Encoding

The surface longitude position data **shall** be encoded in accordance with §A.1.4.2.2 and §A.1.7 of Appendix A.

2.2.3.2.4.8.2 Surface Longitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 5 and 6)

2.2.3.2.4.8.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1")

If "TIME" (T) = 1 (see §2.2.3.2.3.5) in a Surface Position Message, then the time of applicability of the latitude and longitude fields in that message **shall** be an exact 0.2 second UTC epoch.

a. Specifically, the position data in the latitude and longitude fields **shall** be extrapolated forward from the time of validity of the position fix to the time of applicability of the Surface Position Message.

b. The Surface longitude data registers and the encoded longitude subfield **shall** be updated every 200 milliseconds to the next 0.2 UTC Epoch using the velocity data provided for the position fix.

Notes:

1. *The time of validity of the fix is provided with the fix data from the navigation data source and is indicated by the leading edge of the GNSS Time Mark (see §2.2.5.1.6). The time of applicability of the position message is the exact 0.2 second UTC Epoch to which the position data is extrapolated.*

2. *The longitude position registers and encoded longitude subfield should be updated at a time about 100 milliseconds before the time of applicability of the data being loaded into that register (see §2.2.5.2.1 and Appendix A, §A.1.4.2.3.1).*

3. *One method of estimating the position to an exact 0.2 second UTC Epoch is described in the following "Commentary."*

COMMENTARY:

The following example provides one method (not the only method) that longitude given in the Surface Position Message may be extrapolated from the time of validity of the fix (included with the fix from the navigation data source) to the time of applicability of the Surface Position Message. In the example, it is assumed that the "TIME" subfield (see §2.2.3.2.3.5) is "ONE," indicating that the time of applicability of the extrapolated position is an exact 0.2 second UTC Epoch.

Let:

t_{fix}	=	*time of the leading edge of the last received GNSS Time Mark (see §2.2.5.1.6), which is also the time of validity included with the fix from the navigation data source.*
$t_{message}$	=	*time of applicability of the Surface Position Message, is an exact 0.2 second UTC Epoch.*
Δt	=	$t_{message} - t_{fix}$, *in milliseconds*

λ_{fix}	=	*last known longitude position, at time t_{fix}, in degrees*
$\lambda_{message}$	=	*longitude, extrapolated forward to the time of applicability of the Surface Position Message, $t_{message}$*
$\Delta\lambda$	=	$\lambda_{message} - \lambda_{fix}$, *in degrees*
ϕ	=	*approximate latitude (the latitude, ϕ_{fix}, at the time of the fix may be used)*
v_{EW}	=	*last known E-W velocity at time t_{fix}, in knots (positive for easterly velocity)*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\lambda_{message} = \lambda_{fix} + \Delta\lambda$$

$$= \lambda_{fix} + [(v_{EW})/(60 \cos(\phi))] \times (\Delta t / 3600000)$$

$$= \lambda_{fix} + (v_{EW}\,\Delta t) / [(2.16 \times 10^8) \cos(\phi)]$$

(We divide v_{EW} by 60 cos (ϕ) to convert from knots in the E-W direction to degrees of longitude per hour, and divide Δt by 3600 x 1000 to convert from milliseconds to hours.)

The result, $\lambda_{message}$, is to be encoded in the longitude field of the Surface Position Message using the CPR algorithm described in Appendix A, §A.1.7.

2.2.3.2.4.8.2.2 Non-Coupled Case (Estimation, "TIME" (T) = "0")

ADS-B Surface Position Messages with TYPE Codes of 5 and 6 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.4.8.2.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the surface longitude data registers and encoded longitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.4.8.2.1 is not degraded.*

2.2.3.2.4.8.3 Surface Longitude Position Extrapolation/Estimation (non - precision)

2.2.3.2.4.8.3.1 Surface Longitude Position Extrapolation Case (non - precision)

ADS-B Surface Position Messages with TYPE Codes other than 5 or 6 (see §2.2.3.2.3.1) **shall** contain an estimate of the longitude position at a time of applicability that is within 200 milliseconds of the time that the Surface Position Message is transmitted. Essentially, the original data and the encoded longitude **shall** be updated at least as frequently as every 200 milliseconds.

COMMENTARY:

The only difference between longitude position extrapolation in the non-precision case and that of the precision case (§2.2.3.2.3.7.2.1) is the interpretation of what "Δt" means. In the non-precision case, Δt is the elapsed time from the last received position update to the expected time of transmission of an Surface Position Message that is based on the last position update. (In the precision case, Δt is the time interval from the last received leading edge of the GNSS Time Mark to the 0.2 second UTC Epoch which is to be the time of applicability of the Surface Position Message).

Let:

t_{fix}	=	*time validity included with the PVT (position, velocity, time) data from the navigation data source.*
t_{update}	=	*time when the transmitting ADS-B Subsystem receives the most recent PVT (position, velocity, time) data from a navigation data source.*
$t_{message}$	=	*time of applicability of the Surface Position Message*
Δt	=	$t_{message} - t_{update}$*, in milliseconds*
λ_{fix}	=	*last known longitude position, at time* t_{fix}*, in degrees*
$\lambda_{message}$	=	*longitude, extrapolated forward to the time of applicability of the Surface Position Message,* $t_{message}$
$\Delta\lambda$	=	$\lambda_{message} - \lambda_{fix}$*, in degrees*
ϕ	=	*approximate latitude (the latitude,* ϕ_{fix}*, at the time of the fix may be used)*
v_{EW}	=	*last known E-W velocity at time* t_{fix}*, in knots (positive for easterly velocity)*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\lambda_{message} = \lambda_{fix} + \Delta\lambda$$

$$= \lambda_{fix} + [(v_{EW})/(60 \cos(\phi))] \times (\Delta t / 3600000)$$

$$= \lambda_{fix} + (v_{EW}\, \Delta t) / [(2.16 \times 10^{8}) \cos(\phi)]$$

(We divide v_{EW} by 60 cos (ϕ) to convert from knots in the E-W direction to degrees of longitude per hour, and divide Δt by 3600 x 1000 to convert from milliseconds to hours.)

The result, $\lambda_{message}$, is to be encoded in the longitude field of the Surface Position Message using the CPR algorithm described in Appendix A, §A.1.7.

Note: *In order not to introduce excessive error in the estimated longitude, $\lambda_{message}$, the latency, t_{update} - t_{fix}, in the delivery of PVT data from the navigation data source should not be excessive.*

2.2.3.2.4.8.3.2 Surface Longitude Position Estimation Case (non - precision)

ADS-B Surface Position Messages with TYPE Codes other than 5 and 6 (see §2.2.3.2.3.1) may implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the position update requirements given in §2.2.3.2.4.8.3.1. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the sampled data rate is sufficient to satisfy minimum Nyquist criterion. Likewise such techniques may be necessary in order to provide velocity compensation and/or acceleration estimation in the future.

a. If sampled data estimation techniques, e.g., alpha-beta trackers, alpha-beta-gamma trackers, or Kalman filters, are used to periodically update position data, then the maximum sampled data time **shall** not exceed 100 milliseconds.

b. Sampled data implementations **shall** update the surface longitude data registers and encoded longitude data subfield at intervals not to exceed 100 milliseconds.

Note: *The 100 millisecond requirement is necessary in order to insure that the 200 millisecond performance required in §2.2.3.2.3.8.3.1 is not degraded.*

2.2.3.2.4.8.4 Surface Longitude Position Data Retention

The extrapolation and update of longitude data and fields specified in §2.2.3.2.4.8.2 through §2.2.3.2.4.8.3.2 **shall** be limited to no more than two seconds, in the event that the longitude position data is no longer available. At the end of two seconds, the longitude data registers and the encoded longitude field **shall** be set to ALL ZEROs.

2.2.3.2.5 ADS-B Aircraft Identification and Category Messages

Format for the Aircraft Identification and Category Message "ME" field contents is specified in Figure 2-6. Each of the subfields is specified in the following subparagraphs.

Aircraft Identification and Category Message "ME" Field										
Msg Bit #	33 - 37	38 -- 40	41 - 46	47 - 52	53 - 58	59 - 64	65 - 70	71 - 76	77 - 82	83 – 88
"ME" Bit #	1 - 5	6 - 8	9 - 14	15 - 20	21 - 26	27 - 32	33 - 38	39 - 44	45 - 50	51 - 56
Field Name	**TYPE Code [5]**	**ADS-B Emitter Category [3]**	**Ident Char. #1 [6]**	**Ident Char. #2 [6]**	**Ident Char. #3 [6]**	**Ident Char. #4 [6]**	**Ident Char. #5 [6]**	**Ident Char. #6 [6]**	**Ident Char. #7 [6]**	**Ident Char. #8 [6]**
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB

Note: *"[#]" provided in the Field indicates the number of bits in the field.*

Figure 2-6: ADS-B Aircraft Identification and Category Message Format

2.2.3.2.5.1 "TYPE" Code Subfield in ADS-B Aircraft Identification and Category Message

The "TYPE" Code subfield was previously specified for the Airborne Position Message in §2.2.3.2.3.1 and remains the same for the ADS-B Aircraft Identification and Category Message, which uses TYPE Codes 1, 2, 3 and 4 only.

2.2.3.2.5.2 "ADS-B Emitter Category" Subfield in ADS-B Aircraft Identification and Category Message

The "ADS-B Emitter Category" subfield is a 3-bit ("ME" bits 6 through 8, Message bits 38 through 40) field that **shall** be used to identify particular aircraft or vehicle types within the ADS-B Emitter Category Sets A, B, C or D identified by Message Format TYPE Codes 4, 3, 2 and 1, respectively. Each of the ADS-B Emitter Category Sets are specified in Table 2-21.

If the ADS-B Emitter Category is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the "ADS-B Emitter Category" Subfield in the Aircraft Identification and Category Message.

Table 2-21: "ADS-B Emitter Category SET" Code Definitions

ADS-B Emitter Category SET "A"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1	Light (<15,500 lbs.)
2	Small (15,500 to 75,000 lbs.)
3	Large (75,000 to 300,000 lbs.)
4	High-Vortex Large (aircraft such as B-757)
5	Heavy (> 300,000 lbs.)
6	High Performance (>5g acceleration and > 400 knots)
7	Rotorcraft

ADS-B Emitter Category SET "B"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1	Glider / Sailplane
2	Lighter-than-Air
3	Parachutist / Skydiver
4	Ultralight / hang-glider / paraglider
5	Reserved
6	Unmanned Aerial Vehicle
7	Space / Trans-atmospheric vehicle

ADS-B Emitter Category SET "C"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1	Surface Vehicle - Emergency Vehicle
2	Surface Vehicle - Service Vehicle
3	Point Obstacle (includes tethered balloons)
4	Cluster Obstacle
5	Line Obstacle
6 - 7	Reserved

ADS-B Emitter Category SET "D"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1 - 7	Reserved

Note: *The Emitter Category codes 1 to 5 in category set "A" are intended to advise other aircraft of the transmitting aircraft's wake vortex characteristics, and not necessarily the transmitting aircraft's actual maximum takeoff weight. In case of doubt, the next higher aircraft category code should be used.*

2.2.3.2.5.3 "ID Character" Subfield in ADS-B Aircraft Identification and Category Message

Each of the 8 "Ident Character" subfields is a 6-bit field as specified in Figure 2-6.

The 8 "Ident Character" subfields **shall** encode the following information:

a. If the flight identification used in the aircraft flight plan is available (e.g., an airline flight number), then the flight identification used in the flight plan **shall** be encoded.

b. If the flight identification used in the aircraft flight plan is not available, then the Aircraft Registration Marking **shall** be encoded.

c. Surface vehicles should encode their radio call signs.

The character in each of the "Ident Character" subfields is encoded as a 6-bit subset of the International Alphabet Number 5 (IA-5) in accordance with the following documents:

a. ICAO, Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.9.1.2 and Table 3-9.

Note: *The international reference version of International Alphabet No. 5 (IA-5) is defined in full in ICAO, Annex 10, Volume III, Part 1, Amendment No. 82, dated 11/22/2007, Table 8-2.*

b. RTCA DO-181D, §2.2.19.1.13, (EUROCAE ED-73C, §3.23.1.13) and

c. §A.1.4.4 of Appendix A.

2.2.3.2.6 ADS-B Airborne Velocity Messages

Formats for the various Airborne Velocity Messages are further classified by a Subtype Code as identified in the following subparagraphs and Figure 2-7 and Figure 2-8.

Airborne Velocity Message Subtype=1 and "2" "ME" Field															
MSG BIT #	33 - 37	38 - 40	41	42	43 - 45	46	47 - 56	57	58 - 67	68	69	70 - 78	79 - 80	81	82 – 88
"ME" BIT #	1 - 5	6 - 8	9	10	11 - 13	14	15 - 24	25	26 - 35	36	37	38 - 46	47 - 48	49	50 – 56
FIELD NAME	TYPE [5]	Subtype [3]	Intent Change Flag [1]	Reserved-A [1]	NAC_V [3]	E/W Direction Bit [1]	E/W Velocity [10]	N/S Direction Bit [1]	N/S Velocity [10]	Vert Rate Source [1]	Vert Rate Sign [1]	Vert Rate [9]	Reserved-B [2]	Diff from Baro Alt Sign [1]	Diff from Baro Alt [7]
	MSB LSB	MSB LSB			MSB LSB		MSB LSB		MSB LSB			MSB LSB	MSB LSB		MSB LSB

<u>Figure 2-7:</u> ADS-B Airborne Velocity Message Subtype "1&2"

Airborne Velocity Message Subtype=3 and "4" "ME" Field															
MSG BIT #	33 - 37	38 - 40	41	42	43 - 45	46	47 - 56	57	58 - 67	68	69	70 - 78	79 - 80	81	82 – 88
"ME" BIT #	1 - 5	6 - 8	9	10	11 - 13	14	15 - 24	25	26 - 35	36	37	38 - 46	47 - 48	49	50 – 56
FIELD NAME	TYPE [5]	Subtype [3]	Intent Change Flag [1]	Reserved-A [1]	NAC_V [3]	Heading Status Bit [1]	Heading [10]	Airspeed Type [1]	Airspeed [10]	Vert Rate Source [1]	Vert Rate Sign [1]	Vert Rate [9]	Reserved-B [2]	Diff from Baro Alt Sign [1]	Diff from Baro Alt [7]
	MSB LSB	MSB LSB			MSB LSB		MSB LSB		MSB LSB			MSB LSB	MSB LSB		MSB LSB

<u>Figure 2-8:</u> ADS-B Airborne Velocity Message Subtype "3&4"

<u>Note:</u> *The "[#]" provided in the Field description columns of Figure 2-7 and Figure 2-8 indicates the number of bits in the respective FIELD.*

2.2.3.2.6.1 ADS-B Airborne Velocity Message - Subtype=1

a. The Airborne Velocity Message - Subtype=1 is illustrated in Figure 2-7 and **shall** be transmitted by the Airborne ADS-B Transmitting Subsystem when Velocity Over Ground information is available, and the transmitting device is installed in an environment having *NON*-supersonic airspeed capability.

b. The Supersonic Version of the Airborne Velocity Message (i.e., Subtype=2) **shall** be used if either the East/West velocity OR the North/South velocity exceeds 1022 knots. A switch to the normal velocity message (i.e., Subtype=1) **shall** be made if both the East/West and the North/South velocities drop below 1000 knots.

c. The Airborne Velocity Message **shall not** be broadcast if the only valid data is the Intent Change Flag.

(1). Transponder-Based ADS-B Transmitting Subsystems **shall** suppress the broadcast by loading Register 09_{16} with "ALL ZEROs" and then discontinuing updating of the Register until data input is available again. The Transponder will ZERO the Airborne Velocity Message after 2.6 seconds and terminate the broadcast.

(2). Non-Transponder-Based ADS-B Transmitting Subsystems **shall** ZERO the Airborne Velocity Message after 2.6 seconds and terminate the broadcast as specified in §2.2.3.3.2.11 and §2.2.3.3.2.12.

Each of the subfields of the Airborne Velocity Message - Subtype=1 is specified in the following subparagraphs.

2.2.3.2.6.1.1 "TYPE" Code Subfield in Airborne Velocity Message - Subtype=1

The "TYPE" Code subfield was previously specified in §2.2.3.2.3.1 and remains the same for ADS-B Airborne Velocity Messages - Subtype=1 that use TYPE Code 19 only.

2.2.3.2.6.1.2 "Subtype" Code Subfield in Airborne Velocity Message - Subtype=1

The "Subtype" Code subfield is a 3-bit ("ME" bit 6 through 8, Message bit 38 through 40) field that **shall** be used to identify the subtypes of Airborne Velocity Messages as specified in Table 2-22.

Table 2-22: Airborne Velocity Message "Subtype" Code Field Encoding

Coding		Primary Message Contents
(Binary)	(Decimal)	
000	0	Reserved
001	1	Velocity Over Ground (i.e., Ground Speed) under normal airspeed, i.e., non-supersonic, conditions
010	2	Velocity Over Ground (i.e., Ground Speed) under supersonic conditions
011	3	Airspeed and Heading Information when Velocity Over Ground information is not available and airspeed conditions are normal, i.e., non-supersonic
100	4	Airspeed and Heading Information when Velocity Over Ground information is not available and airspeed conditions are supersonic
101	5	Reserved
110	6	Reserved
111	7	Reserved

The ADS-B Airborne Velocity Messages - Subtype=1 **shall** use a Subtype encoding of "1."

2.2.3.2.6.1.3 "Intent Change Flag" Subfield in Airborne Velocity Messages - Subtype=1

The "Intent Change Flag" subfield is a 1-bit ("ME" bit 9, Message bit 41) field that **shall** be used to indicate a change in intent as specified in Table 2-23, and transmitted in the Airborne Velocity Message.

Table 2-23: "Intent Change Flag" Encoding

Coding	Meaning
0	No Change in Intent
1	Intent Change

a. Mode-S Transponder Implementations

An Intent Change event **shall** be triggered 4 seconds after the detection of new information being inserted in GICB Registers 40_{16} to 42_{16}. This results in the "Intent Change Flag" being set to ONE (1) and the code remains set for 18 ±1 seconds following the intent change.

Notes:

1. *GICB Register 43_{16} is not included since it contains dynamic data that will be continuously changing.*

2. *A four second delay is required to provide for settling time for intent data derived from manually set devices.*

b. Non-Transponder-Based Implementations

Non-Transponder-Based transmission devices do not implement the Target State and Status Messages and therefore do not set the "Intent Change Flag." Therefore, such devices **shall** set the "Intent Change Flag" to ZERO at all times.

2.2.3.2.6.1.4 "Reserved Bit-A" Subfield in Airborne Velocity Messages – Subtype=1

The "Reserved Bit-A" subfield is a 1-bit ("ME" bit 10, Message bit 42) field that **shall** be set to ZERO (0) in all ADS-B Transmitting Subsystems that comply with these MOPS.

This "Reserved Bit-A" subfield was identified in RTCA DO-260A as the "IFR Capability Flag" subfield, and was required to be set to ONE only for transmitting aircraft that had the capability for applications requiring ADS-B equipage Class "A1" or above. The "IFR Capability Flag" has been eliminated from the ADS-B MASPS (RTCA DO-242B), and so has been removed from these requirements for the 1090ES MOPS.

2.2.3.2.6.1.5 "NAC_V" Subfield in Airborne Velocity Messages - Subtype=1

The "NAC_V" subfield is a 3-bit ("ME" bits 11 through 13, Message bits 43 through 45) field that **shall** be used to indicate the Navigation Accuracy Category for Velocity as specified in Table 2-25.

The ADS-B Transmitting Subsystem **shall** accept, via an appropriate data interface, data from which the own-vehicle Navigation Accuracy Category for Velocity (NAC_V) may be inferred, and it **shall** use such data to establish the NAC_V subfields in transmitted ADS-B Airborne Velocity Messages.

If the external data source provides 95% accuracy figures of merit for horizontal and vertical velocity, then the ADS-B Transmitting Subsystem **shall** determine the value of the NAC_V field in the Airborne Velocity Messages, Subtypes 1, 2, 3 and 4 (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4, respectively) according to Table 2-25.

Note: *Appendix J describes the manner in which GNSS position sources, which do not output velocity accuracy, can be characterized so that a velocity accuracy value associated with the position source can be input into ADS-B equipment as part of the installation process.*

Table 2-25: Determining NAC_V Based on Position Source Declared Horizontal Velocity Error

Navigation Accuracy Category for Velocity		
Coding		Horizontal Velocity Error
(Binary)	(Decimal)	
000	0	≥ 10 m/s
001	1	< 10 m/s
010	2	< 3 m/s
011	3	< 1 m/s
100	4	< 0.3 m/s

2.2.3.2.6.1.6 "East/West Direction Bit" Subfield in Airborne Velocity Messages - Subtype=1

The "East/West Direction Bit" subfield is a 1-bit ("ME" bit 14, Message bit 46) field that **shall** be used to indicate the direction of the East/West Velocity Vector as specified in Table 2-28.

Table 2-28: "East/West Direction Bit" Encoding

Coding	Meaning
0	EAST
1	WEST

2.2.3.2.6.1.7 "East/West Velocity" Subfield in Airborne Velocity Messages - Subtype=1

The "East/West Velocity" subfield is a 10-bit ("ME" bit 15 through 24, Message bit 47 through 56) field that **shall** be used to report the East/West subsonic Velocity (in knots) of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "East/West Velocity" subfield **shall** be as shown in Table 2-29.

Table 2-29: "East/West Velocity" (subsonic) Encoding

Coding		Meaning
(Binary)	(Decimal)	(E/W Velocity in knots) (subsonic)
00 0000 0000	0	No E/W Velocity information available
00 0000 0001	1	E/W Velocity is ZERO
00 0000 0010	2	E/W Velocity = 1 knot
00 0000 0011	3	E/W Velocity = 2 knots
***	***	***
11 1111 1110	1022	E/W Velocity = 1021 knots
11 1111 1111	1023	E/W Velocity > 1021.5 knots

Notes:

1. *The encoding shown in the table represents Positive Magnitude data only. Direction is given completely by the East/West Direction Bit.*

2. *Raw data used to establish the East/West Velocity Subfield will normally have more resolution (i.e., more bits) than that required by the East/West Velocity Subfield. When converting such data to the East/West Velocity Subfield, the accuracy of the data must be maintained such that it is not worse than ±½ LSB where the LSB is that of the East/West Velocity subfield.*

3. *All velocity vector components are to be referenced to WGS-84 or to a coordinate system consistent with WGS-84.*

2.2.3.2.6.1.8 "North/South Direction Bit" Subfield in Airborne Velocity Messages - Subtype=1

The "North/South Direction Bit" subfield is a 1-bit ("ME" bit 25, Message bit 57) field that **shall** be used to indicate the direction of the North/South Velocity Vector as shown in Table 2-30.

Table 2-30: "North/South Direction Bit" Encoding

Coding	Meaning
0	NORTH
1	SOUTH

2.2.3.2.6.1.9 "North/South Velocity" Subfield in Airborne Velocity Messages - Subtype=1

The "North/South Velocity" subfield is a 10-bit ("ME" bit 26 through 35, Message bit 58 through 67) field that **shall** be used to report the North/South subsonic Velocity (in knots) of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "North/South Velocity" subfield **shall** be as shown in Table 2-31.

Table 2-31: "North/South Velocity" (subsonic) Encoding

Coding		Meaning
(Binary)	(Decimal)	(N/S Velocity in knots) (subsonic)
00 0000 0000	0	No N/S Velocity information available
00 0000 0001	1	N/S Velocity is ZERO
00 0000 0010	2	N/S Velocity = 1 knot
00 0000 0011	3	N/S Velocity = 2 knots
***	***	***
11 1111 1110	1022	N/S Velocity = 1021 knots
11 1111 1111	1023	N/S Velocity > 1021.5 knots

Notes:

1. *The encoding shown in the table represents Positive Magnitude data only. Direction is given completely by the North/South Direction Bit.*

2. *Raw data used to establish the North/South Velocity Subfield will normally have more resolution (i.e., more bits) than that required by the North/South Velocity Subfield. When converting such data to the North/South Velocity Subfield, the accuracy of the data **shall** be maintained such that it is not worse than ±½ LSB where the LSB is that of the North/South Velocity subfield.*

3. *All velocity vector components are to be referenced to WGS-84 or to a coordinate system consistent with WGS-84.*

2.2.3.2.6.1.10 "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=1

The "Source Bit for Vertical Rate " subfield is a 1-bit ("ME" bit 36, Message bit 68) field that **shall** be used to indicate the source of Vertical Rate information by being encoded as specified in Table 2-32.

Table 2-32: "Source Bit for Vertical Rate" Encoding

Coding	Meaning
0	Vertical Rate information from Geometric Source (GNSS or INS)
1	Vertical Rate information from Barometric Source

2.2.3.2.6.1.11 "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=1

The "Sign Bit for Vertical Rate" subfield is a 1-bit ("ME" bit 37, Message bit 69) field that **shall** be used to indicate the direction of the "Vertical Rate" Vector as shown in Table 2-33.

Table 2-33: "Sign Bit for Vertical Rate" Encoding

Coding	Meaning
0	UP
1	DOWN

2.2.3.2.6.1.12 "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=1

The "Vertical Rate" subfield is a 9-bit ("ME" bit through 38 through 46, Message bit 70 through 78) field that is used to report the Vertical Rate (in feet/minute) of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "Vertical Rate" subfield **shall** be as shown in Table 2-34.

Table 2-34: "Vertical Rate" Encoding

Coding		Meaning
(Binary)	(Decimal)	(Vertical Rate in feet / minute)
0 0000 0000	0	No Vertical Rate information available
0 0000 0001	1	Vertical Rate is ZERO
0 0000 0010	2	Vertical Rate = 64 feet / minute
0 0000 0011	3	Vertical Rate = 128 feet / minute
***	***	***
1 1111 1110	510	Vertical Rate = 32576 feet / minute
1 1111 1111	511	Vertical Rate > 32608 feet / minute

Note: *The encoding shown in the table represents **Positive Magnitude data only**. Direction is given completely by the "Sign Bit for Vertical Rate" subfield.*

2.2.3.2.6.1.13 "Reserved Bits-B" Subfield in Airborne Velocity Messages – Subtype=1

The "Reserved Bits-B" subfield is a 2-bit ("ME" bits 47 – 48, Message bits 79 – 80) field that **shall** be set to ZERO (binary 00) in all ADS-B Transmitting Subsystems that comply with these MOPS.

This "Reserved Bits-B" subfield was identified in RTCA DO-260 as the "Turn Indicator" subfield, and was required to be set to ZERO (binary 00) for all ADS-B Transmitting and

Receiving Subsystems that comply with that document also. The "Turn Indicator" was eliminated from the ADS-B MASPS (RTCA DO-242A), and so has been removed from the requirements for the 1090 MHz Extended Squitter data link.

2.2.3.2.6.1.14 "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=1

The "Difference From Barometric Altitude Sign Bit" subfield is a 1-bit ("ME" bit 49, Message bit 81) field that **shall** be used to indicate the direction of the GNSS Altitude Source data as shown in Table 2-35.

<u>Table 2-35:</u> "Difference From Barometric Altitude Sign Bit" Encoding

Coding	Meaning
0	Geometric (GNSS or INS) Altitude Source data is greater than (above) Barometric
1	Geometric (GNSS or INS) Altitude Source data is less than (below) Barometric

2.2.3.2.6.1.15 "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=1

The "Difference From Barometric Altitude" subfield is a 7-bit ("ME" bits 50 through 56, Message bits 82 through 88) field that is used to report the difference between Geometric (GNSS or INS) Altitude Source data and Barometric Altitude when both types of Altitude Data are available and valid. The difference between barometric altitude and GNSS Height Above Ellipsoid (HAE) is preferred. However, GNSS Altitude (MSL) may be used when airborne position is being reported using TYPE Codes 11 through 18. If airborne position is being reported using TYPE Codes 9 or 10, only GNSS Height Above the Ellipsoid (HAE) may be used. For TYPE Codes 9 and 10, if GNSS Height Above the Ellipsoid (HAE) is not available, then the Difference from Barometric Altitude subfield **shall** be set to ALL ZEROs.

<u>Note:</u> *The basis for the barometric altitude difference (either GNSS HAE or Altitude MSL) must be used consistently for the reported difference.*

Range, Resolution, and No Data encoding of the "Difference From Barometric Altitude" subfield **shall** be as shown in Table 2-36.

Table 2-36: "Difference From Barometric Altitude" Encoding

Coding (Binary)	Coding (Decimal)	Meaning (Geometric (GNSS or INS) Altitude Source data Difference in feet)
000 0000	0	No GNSS Altitude Source data Difference information available
000 0001	1	GNSS Altitude Source data Difference is ZERO
000 0010	2	GNSS Altitude Source data Difference = 25 feet
000 0011	3	GNSS Altitude Source data Difference = 50 feet
***	***	***
111 1110	126	GNSS Altitude Source data Difference = 3125 feet
111 1111	127	GNSS Altitude Source data Difference > 3137.5 feet

Note: *The encoding shown in the table represents **Positive Magnitude data only**. Direction is given completely by the Difference From Barometric Altitude Sign Bit.*

2.2.3.2.6.2 ADS-B Airborne Velocity Message - Subtype=2

a. The Airborne Velocity Message - Subtype=2 is illustrated in Figure 2-7 and **shall** be transmitted by the Airborne ADS-B Transmitting Subsystem when Velocity Over Ground information is available, and the transmitting device is installed in an environment having a Supersonic airspeed capability.

b. The Supersonic Version of the Airborne Velocity Message (i.e., Subtype=2) **shall** be used if either the East/West Velocity OR the North/South Velocity exceeds 1022 knots. A switch to the normal Airborne Velocity Message (i.e., Subtype=1) **shall** be made if both the East/West and the North/South Velocities drop below 1000 knots.

c. The Airborne Velocity Message **shall not** be broadcast if the only valid data is the Intent Change Flag.

(1). Transponder-Based ADS-B Transmitting Subsystems **shall** suppress the broadcast by loading Register 09_{16} with "ALL ZEROs" and then discontinuing updating of the Register until data input is available again. The Transponder will ZERO the Velocity Message after 2.6 seconds and terminate the broadcast.

(2). Non-Transponder-Based ADS-B Transmitting Subsystems **shall** ZERO the Velocity Message after 2.6 seconds and terminate the broadcast, as specified in §2.2.3.3.2.11 and §2.2.3.3.2.12.

Each of the subfields of the Airborne Velocity Message - Subtype=2 is specified in the following subparagraphs.

2.2.3.2.6.2.1 "TYPE" Code Subfield in Airborne Velocity Messages - Subtype=2

The "TYPE" Code subfield was previously specified in §2.2.3.2.3.1 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2 which use TYPE Code 19 only.

2.2.3.2.6.2.2 "Subtype" Code Subfield in Airborne Velocity Messages - Subtype=2

The "Subtype" Code subfield was previously specified in §2.2.3.2.6.1.2 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2 which **shall** use a subtype encoding of "2."

2.2.3.2.6.2.3 "Intent Change Flag" Subfield in Airborne Velocity Messages - Subtype=2

The "Intent Change Flag" subfield was previously specified in §2.2.3.2.6.1.3 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.4 "Reserved Bit-A" Subfield in Airborne Velocity Messages – Subtype=2

The "Reserved Bit-A" subfield was previously specified in §2.2.3.2.6.1.4 and remains the same for ADS-B Airborne Velocity Messages – Subtype=2.

2.2.3.2.6.2.5 "NAC_V" Subfield in Airborne Velocity Messages - Subtype=2

The "Navigation Accuracy Category - Velocity" (NAC_V) subfield was previously specified in §2.2.3.2.6.1.5 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.6 "East/West Direction Bit" Subfield in Airborne Velocity Messages - Subtype=2

The "East/West Direction Bit" subfield was previously specified in §2.2.3.2.6.1.6 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.7 "East/West Velocity" Subfield in Airborne Velocity Messages - Subtype=2

The "East/West Velocity" subfield is a 10-bit ("ME" bit 15 through 24, Message bit 47 through 56) field that **shall** be used to report the East/West supersonic Velocity (in knots) of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "East/West Velocity" subfield **shall** be as shown in Table 2-37.

Table 2-37: "East/West Velocity" (supersonic) Encoding

Coding		Meaning
(Binary)	(Decimal)	(E/W Velocity in knots) (supersonic)
00 0000 0000	0	No E/W Velocity information available
00 0000 0001	1	E/W Velocity is ZERO
00 0000 0010	2	E/W Velocity = 4 knots
00 0000 0011	3	E/W Velocity = 8 knots
***	***	***
11 1111 1110	1022	E/W Velocity = 4084 knots
11 1111 1111	1023	E/W Velocity > 4086 knots

Notes:

1. *The encoding shown in the table represents Positive Magnitude data only. Direction is given completely by the East/West Direction Bit.*

2. *Raw data used to establish the East/West Velocity Subfield will normally have more resolution (i.e., more bits) than that required by the East/West Velocity Subfield. When converting such data to the East/West Velocity Subfield, the accuracy of the data must be maintained such that it is not worse than ±½ LSB where the LSB is that of the East/West Velocity subfield.*

3. *All velocity vector components are to be referenced to WGS-84 or to a coordinate system consistent with WGS-84.*

2.2.3.2.6.2.8 "North/South Direction Bit" Subfield in Airborne Velocity Messages - Subtype=2

The "North/South Direction Bit" subfield was previously specified in §2.2.3.2.6.1.8 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.9 "North/South Velocity" Subfield in Airborne Velocity Messages - Subtype=2

The "North/South Velocity" subfield is a 10-bit ("ME" bits 26 through 35, Message bits 58 through 67) field that **shall** be used to report the North/South Supersonic Velocity (in knots) of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "North/South Velocity" subfield **shall** be as shown in Table 2-38.

<u>Table 2-38:</u> "North/South Velocity" (supersonic) Encoding

Coding		**Meaning**
(Binary)	(Decimal)	(N/S Velocity in knots)(supersonic)
00 0000 0000	0	No N/S Velocity information available
00 0000 0001	1	N/S Velocity is ZERO
00 0000 0010	2	N/S Velocity = 4 knots
00 0000 0011	3	N/S Velocity = 8 knots
***	***	***
11 1111 1110	1022	N/S Velocity = 4084 knots
11 1111 1111	1023	N/S Velocity > 4086 knots

Notes:

1. *The encoding shown in the table represents Positive Magnitude data only. Direction is given completely by the North/South Direction Bit.*

2. *Raw data used to establish the North/South Velocity Subfield will normally have more resolution (i.e., more bits) than that required by the North/South Velocity Subfield. When converting such data to the North/South Velocity Subfield, the accuracy of the data must be maintained such that it is not worse than ±½ LSB where the LSB is that of the North/South Velocity subfield.*

3. *All velocity vector components are to be referenced to WGS-84 or to a coordinate system consistent with WGS-84.*

2.2.3.2.6.2.10 "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=2

The "Source Bit for Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.10 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.11 "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=2

The "Sign Bit for Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.11 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.12 "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=2

The "Vertical Rate" subfield was previously dspecified in §2.2.3.2.6.1.12 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.13 "Reserved Bits-B" Subfield in Airborne Velocity – Subtype=2 Messages

The "Reserved Bits-B" subfield was previously specified in §2.2.3.2.6.1.13 and remains the same for ADS-B Airborne Velocity – Subtype=2 Messages.

2.2.3.2.6.2.14 "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=2

The "Difference From Barometric Altitude Sign Bit" subfield was previously specified in §2.2.3.2.6.1.14 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.2.15 "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=2

The "Difference From Barometric Altitude" subfield was previously specified in §2.2.3.2.6.1.15 and remains the same for ADS-B Airborne Velocity Messages - Subtype=2.

2.2.3.2.6.3 ADS-B Airborne Velocity Message - Subtype=3

a. The Airborne Velocity Message - Subtype=3 is illustrated in Figure 2-8 and **shall** be transmitted by the Airborne ADS-B Transmitting Subsystem when Velocity Over Ground information is not available, and the transmitting device is installed in an environment having *NON*-supersonic airspeed capability.

b. The Supersonic Version of the Airborne Velocity Message (i.e., Subtype=4) **shall** be used if the airspeed exceeds 1022 knots. A switch to the normal Velocity Message (i.e., Subtype=3) **shall** be made if the airspeed drops below 1000 knots.

c. The Airborne Velocity Message **shall** not be broadcast if the only valid data is the Intent Change Flag.

(1). Transponder-Based ADS-B Transmitting Subsystems **shall** suppress the broadcast by loading Register 09_{16} with all “ZEROs” and then discontinuing updating of the Register until data input is available again. The Transponder will ZERO the Velocity Message after 2 seconds and terminate broadcast after 60 seconds, as specified in RTCA DO-181D (EUROCAE ED-73C).

(2). Non-Transponder-Based ADS-B Transmitting Subsystems **shall** ZERO the Velocity Message after 2 seconds and terminate broadcast after 60 seconds, as specified in §2.2.3.3.2.11 and §2.2.3.3.2.12.

Each of the subfields of the Airborne Velocity Message - Subtype=3 is specified in the following subparagraphs.

2.2.3.2.6.3.1 “TYPE” Code Subfield in Airborne Velocity Messages - Subtype=3

The “TYPE” Code subfield was previously specified in §2.2.3.2.3.1 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3 which use TYPE Code 19 only.

2.2.3.2.6.3.2 “Subtype” Code Subfield in Airborne Velocity Messages - Subtype=3

The “Subtype” Code subfield was previously specified in §2.2.3.2.6.1.2 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3 which **shall** use a subtype encoding of “3.”

2.2.3.2.6.3.3 “Intent Change Flag” Subfield in Airborne Velocity Messages - Subtype=3

The “Intent Change Flag” subfield was previously specified in §2.2.3.2.6.1.3 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.3.4 “Reserved Bit-A” Subfield in Airborne Velocity Messages – Subtype=3

The “Reserved Bit-A” subfield was previously specified in §2.2.3.2.6.1.4 and remains the same for ADS-B Airborne Velocity Messages – Subtype=3.

2.2.3.2.6.3.5 "NAC_V" Subfield in Airborne Velocity Messages - Subtype=3

The "Navigation Accuracy Category - Velocity" (NAC_V) subfield was previously specified in §2.2.3.2.6.1.5 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.3.6 "Heading Status Bit" Subfield in Airborne Velocity Messages - Subtype=3

The "Heading Status Bit " subfield is a 1-bit ("ME" bit 14, Message bit 46) field that **shall** be used to indicate the availability of "Heading" information as shown in Table 2-39.

<u>Table 2-39:</u> "Heading Status Bit" Encoding

Coding	Meaning
0	Heading Data is NOT Available
1	Heading Data is Available

2.2.3.2.6.3.7 "Heading" Subfield in Airborne Velocity Messages - Subtype=3

The "Heading" subfield is a 10-bit ("ME" bits 15 through 24, Message bits 47 through 56) field that **shall** be used to report the "Heading" (in degrees) of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "Heading" subfield **shall** be as shown in Table 2-40.

<u>Table 2-40:</u> "Heading" Encoding

Coding		Meaning
(Binary)	(Decimal)	(Heading in degrees)
00 0000 0000	0	Heading is ZERO
00 0000 0001	1	Heading = 0.3515625 degrees
00 0000 0010	2	Heading = 0.703125 degrees
00 0000 0011	3	Heading = 1.0546875 degrees
***	***	***
01 1111 1111	511	Heading = 179.6484375 degrees
10 0000 0000	512	Heading = 180.0 degrees
10 0000 0001	513	Heading = 180.3515625 degrees
10 0000 0010	514	Heading = 180.703125 degrees
***	***	***
11 1111 1110	1022	Heading = 359.296875 degrees
11 1111 1111	1023	Heading = 359.6484375 degrees

<u>Notes:</u>

1. *The encoding shown in the table represents an angular weighted binary encoding in degrees clockwise from True or Magnetic North. The MSB represents a bit weighting of 180 degrees, while the LSB represents a bit weighting of 360/1024 degrees.*

2. *Raw data used to establish the Heading Subfield will normally have more resolution (i.e., more bits) than that required by the Heading Subfield. When converting such data to the Heading Subfield, the accuracy of the data must be maintained such that it is not worse than ±½ LSB where the LSB is that of the Heading subfield.*

3. *The reference direction for Heading (whether True North or Magnetic North) is indicated in the Horizontal Reference Direction (HRD) field of the Aircraft Operational Status Message (§2.2.3.2.7.2.13).*

2.2.3.2.6.3.8 "Airspeed Type" Subfield in Airborne Velocity Messages - Subtype=3

The "Airspeed Type" subfield is a 1-bit ("ME" bit 25, Message bit 57) field that **shall** be used to indicate the type of subsonic airspeed data provided in the "Airspeed" Subfield (see §2.2.3.2.6.3.9) and is coded as specified in Table 2-41.

Table 2-41: "Airspeed Type" (subsonic) Encoding

Coding	Meaning
0	Airspeed Type is Indicated Airspeed (IAS)
1	Airspeed Type is True Airspeed (TAS)

2.2.3.2.6.3.9 "Airspeed" Subfield in Airborne Velocity Messages - Subtype=3

The "Airspeed" subfield is a 10-bit ("ME" bit 26 through 35, Message bit 58 through 67) field that **shall** be used to report the subsonic Airspeed, either Indicated or True, of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "Airspeed" subfield **shall** be as shown in Table 2-42.

Table 2-42: "Airspeed" (IAS or TAS) (subsonic) Encoding

Coding		Meaning
(Binary)	(Decimal)	(Airspeed in knots) (subsonic)
00 0000 0000	0	No Airspeed information available
00 0000 0001	1	Airspeed is ZERO
00 0000 0010	2	Airspeed = 1 knot
00 0000 0011	3	Airspeed = 2 knots
***	***	***
11 1111 1110	1022	Airspeed = 1021 knots
11 1111 1111	1023	Airspeed > 1021.5 knots

Note: *The encoding shown in the table represents **Positive Magnitude data only**, since Airspeed Data (IAS or TAS) is always considered to be positive. All velocity vector components are to be referenced to WGS-84 or to a coordinate system consistent with WGS-84.*

2.2.3.2.6.3.10 "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=3

The "Source Bit for Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.10 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.3.11 "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=3

The "Sign Bit for Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.11 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.3.12 "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=3

The "Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.12 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.3.13 "Reserved Bits-B" Subfield in Airborne Velocity Messages – Subtype=3

The "Reserved Bits-B" subfield was previously specified in §2.2.3.2.6.1.13 and remains the same for ADS-B Airborne Velocity – Subtype=3 Messages.

2.2.3.2.6.3.14 "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=3

The "Difference From Barometric Altitude Sign Bit" subfield was previously specified in §2.2.3.2.6.1.14 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.3.15 "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=3

The "DIFFERENCE FROM BAROMETRIC ALTITUDE" subfield was previously specified in §2.2.3.2.6.1.15 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.4 ADS-B Airborne Velocity Message - Subtype=4

a. The Airborne Velocity Message - Subtype=4 is illustrated in Figure 2-8 and **shall** be transmitted by the Airborne ADS-B Transmitting Subsystem when Velocity Over Ground information is ***NOT*** available, and the transmitting device is installed in an environment having Supersonic airspeed capability.

b. The Supersonic Version of the Airborne Velocity Message (i.e., Subtype=4) **shall** be used if the airspeed exceeds 1022 knots. A switch to the normal Velocity Message (i.e., Subtype=3) **shall** be made if the airspeed drops below 1000 knots.

c. The Airborne Velocity Message **shall not** be broadcast if the only valid data is the Intent Change Flag.

(1). Transponder-Based ADS-B Transmitting Subsystems **shall** suppress the broadcast by loading Register 09_{16} with “ALL ZEROs” and then discontinuing updating of the Register until data input is available again. The Transponder will ZERO the Velocity Message after 2.6 seconds and terminate the broadcast.

(2). Non-Transponder-Based ADS-B Transmitting Subsystems **shall** ZERO the Velocity Message after 2.6 seconds and terminate the broadcast, as specified in §2.2.3.3.2.11 and §2.2.3.3.2.12.

Each of the subfields of the Airborne Velocity Message - Subtype=4 is specified in the following subparagraphs.

2.2.3.2.6.4.1 “TYPE” Code Subfield in Airborne Velocity Messages - Subtype=4

The “TYPE” Code subfield was previously specified in §2.2.3.2.3.1 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4 which use TYPE Code 19 only.

2.2.3.2.6.4.2 “Subtype” Code Subfield in Airborne Velocity Messages - Subtype=4

The “Subtype” Code subfield was previously specified in §2.2.3.2.6.1.2 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3 which **shall** use a subtype encoding of “4.”

2.2.3.2.6.4.3 “Intent Change Flag” Subfield in Airborne Velocity Messages - Subtype=4

The “Intent Change Flag” subfield was previously specified in §2.2.3.2.6.1.3 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.4 “Reserved Bit-A” Subfield in Airborne Velocity Messages – Subtype=4

The “Reserved Bit-A” subfield was previously specified in §2.2.3.2.6.1.4 and remains the same for ADS-B Airborne Velocity Messages – Subtype=4.

2.2.3.2.6.4.5 “NAC_V” Subfield in Airborne Velocity Messages - Subtype=4

The “Navigation Accuracy Category - Velocity” (NAC_V) subfield was previously specified in §2.2.3.2.6.1.5 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.6 "Heading Status Bit" Subfield in Airborne Velocity Messages - Subtype=4

The "Heading Status Bit" subfield was previously specified in §2.2.3.2.6.3.6 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.7 "Heading" Subfield in Airborne Velocity Messages - Subtype=4

The "Heading" subfield was previously specified in §2.2.3.2.6.3.7 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.8 "Airspeed Type" Subfield in Airborne Velocity Messages - Subtype=4

The "Airspeed Type" subfield is a 1-bit ("ME" bit 25, Message bit 57) field that **shall** be used to indicate the type of supersonic airspeed data provided in the "Airspeed" Subfield (see §2.2.3.2.6.4.9) and is coded as specified in Table 2-43.

Table 2-43: "Airspeed Type" (supersonic) Encoding

Coding	Meaning
0	Airspeed Type is Indicated Airspeed (IAS)
1	Airspeed Type is True Airspeed (TAS)

2.2.3.2.6.4.9 "Airspeed" Subfield in Airborne Velocity Messages - Subtype=4

The "Airspeed" subfield is a 10-bit ("ME" bit 26 through 35, Message bit 58 through 67) field that **shall** be used to report the subsonic Airspeed, either Indicated or True, of the ADS-B Transmitting Subsystem.

Range, Resolution, and No Data encoding of the "Airspeed" subfield **shall** be as shown in Table 2-44.

Table 2-44: "Airspeed" (IAS or TAS) (supersonic) Encoding

Coding		Meaning (Airspeed in knots) (supersonic)
(Binary)	(Decimal)	
00 0000 0000	0	No Airspeed information available
00 0000 0001	1	Airspeed is ZERO
00 0000 0010	2	Airspeed = 4 knot
00 0000 0011	3	Airspeed = 8 knots
***	***	***
11 1111 1110	1022	Airspeed = 4084 knots
11 1111 1111	1023	Airspeed > 4086 knots

Note: *The encoding shown in the table represents **Positive Magnitude data only**, since Airspeed Data (IAS or TAS) is always considered to be positive. All velocity vector components are to be referenced to WGS-84 or to a coordinate system consistent with WGS-84.*

2.2.3.2.6.4.10 "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=4

The "Source Bit for Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.10 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.11 "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=4

The "Sign Bit for Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.11 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.12 "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=4

The "Vertical Rate" subfield was previously specified in §2.2.3.2.6.1.12 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.4.13 "Reserved Bits-B" Subfield in Airborne Velocity Messages – Subtype=4

The "Reserved Bits-B subfield was previously specified in §2.2.3.2.6.1.13 and remains the same for ADS-B Airborne Velocity – Subtype=4 Messages.

2.2.3.2.6.4.14 "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=4

The "Difference From Barometric Altitude Sign Bit" subfield was previously specified in §2.2.3.2.6.1.14 and remains the same for ADS-B Airborne Velocity Messages - Subtype=3.

2.2.3.2.6.4.15 "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=4

The "Difference From Barometric Altitude" subfield was previously specified in §2.2.3.2.6.1.15 and remains the same for ADS-B Airborne Velocity Messages - Subtype=4.

2.2.3.2.6.5 ADS-B Airborne Velocity Messages - Subtypes "5, 6, & 7"

ADS-B Airborne Velocity Messages are not specified for Subtypes "5," "6" or "7" and **shall** be considered to be Reserved for future expansion of Velocity Information Type Messages.

2.2.3.2.7 ADS-B Periodic Status and Event-Driven Messages

2.2.3.2.7.1 "Target State and Status" Messages

The "Target State and Status" Message is used to provide the current state of an airborne aircraft in navigating to its intended trajectory and the status of the aircraft's navigation data source and TCAS/ACAS systems. For this version of these MOPS the Target State and Status Message with Subtype=1 is defined to convey information on the aircraft's target heading and altitude (i.e. Target State information) as well as information on the status of the navigation data being used by ADS-B and the status of the aircraft TCAS systems. The format of the Target State and Status Message **shall** be as specified in Figure 2-9, while further definition of each of the subfields **shall** be as specified in the subsequent paragraphs.

Note: *The provisions of RTCA DO-260 related to TCP/TCP+1 were removed from the initial publication of RTCA DO-260A, and provisions for a Target State and Status Message were defined using the same message TYPE Code value (i.e, TYPE Code = 29) as previously defined by RTCA DO-260 for the Aircraft Trajectory Intent Messages that conveyed TCP/TCP+1 information. It is not expected that any implementation based on RTCA DO-260 would have implemented the messages for TCP and TCP+1. However, for purposes of backward compatibility RTCA DO-260A required for a TYPE Code=29 message that "ME" bit 11 always be set to ZERO (0), which would result in a RTCA DO-260 conformant ADS-B receiver not attempting to make use of the remaining contents of the message. Likewise, any TYPE Code=29 message transmitted by an implementation based on DO-260 that has incorrectly set "ME" bit 11 set to ONE (1) (i.e., indicating a valid TCP/TCP+1 Message is being transmitted) should be discarded.*

Target State and Status Message			
Msg Bit #	33 ----------- 37	38 --------- 39	40 --------------------------- 88
"ME" Bit #	1 -------------- 5	6 ------------ 7	8 ----------------------------- 56
Field Name	**TYPE Code = 29 (11101) [5]**	**Subtype Code [2]**	**Intent/Status Information (see §2.2.3.2.7.1.3) [49]**
	MSB LSB	MSB LSB	MSB LSB

Figure 2-9: "Target State and Status" Message Format

2.2.3.2.7.1.1 "TYPE" Code Subfield in Target State and Status Messages

The "TYPE" Code subfield was previously specified for the Airborne Position Message in §2.2.3.2.3.1 and **shall** use the same subfield format for the Target State and Status Message, which uses a TYPE Code of 29.

2.2.3.2.7.1.2 "Subtype" Code Subfield in Target State and Status Messages

The "Subtype" Code subfield is a 2-bit ("ME" bits 6 and 7, Message bits 38 and 39) field that **shall** be used to identify if the format of the remainder of the Target State and Status Message. The "Subtype" subfield **shall** be encoded in accordance with Table 2-45. ADS-B Transmitting Subsystems that comply with these MOPS shall transmit a Subtype Code equal to ONE (1).

Table 2-45: "Subtype" Code Subfield Encoding

Coding (Binary)	Coding (Decimal)	Meaning
00	0	**Reserved** (Target State and Status information was defined in RTCA DO-260A)
01	1	Target State and Status information is provided in the subsequent subfields of the message (see §2.2.3.2.7.1.3)
10	2	Reserved
11	3	Reserved

2.2.3.2.7.1.3 Target State and Status Message (Subtype=1)

"Target State and Status" information is conveyed by the Target State and Status Message (TYPE=29) when the Subtype=ONE (1). The format of the Target State and Status Message for ADS-B Transmitting Subsystems that comply with these MOPS **shall** be in accordance with Figure 2-10.

Msg Bit #	33 ----- 37	38 ----- 39	40	41	42 ------------------------52	53 --------------------------- 61
"ME" Bit #	1 ------ 5	6 ----- 7	8	9	10 ------------------------ 20	21 -------------------------- 29
Field Name	TYPE Code =29 (1 1 1 0 1) [5]	Subtype=1 (0 1) [2]	SIL Supplement [1]	Selected Altitude Type [1]	MCP/FCU Selected Altitude ***or*** FMS Selected Altitude [11]	Barometric Pressure Setting (Minus 800 millibars) [9]
	MSB LSB	MSB LSB			MSB LSB	MSB LSB

Msg Bit #	62	63	64 ---------------- 71	72 -----------------75	76	77 ---------- 78
"ME" Bit #	30	31	32 ---------------- 39	40 ---------------- 43	44	45 ----------- 46
Field Name	Selected Heading Status [1]	Selected Heading Sign [1]	Selected Heading [8]	Navigation Accuracy Category_Position (NAC_P) [4]	Navigation Integrity Category_Baro (NIC_{BARO}) [1]	Source Integrity Level (SIL) [2]
			MSB LSB	MSB LSB		MSB LSB

Msg Bit #	79	80	81	82	83	84	85	86 -------- 88
"ME" Bit #	47	48	49	50	51	52	53	54 -------- 56
Field Name	Status of MCP / FCU Mode Bits [1]	Autopilot Engaged [1]	VNAV Mode Engaged [1]	Altitude Hold Mode [1]	Reserved For ADS-R Flag [1]	Approach Mode [1]	TCAS Operational [1]	Reserved [3]
								MSB LSB

<u>Figure 2-10:</u> "Target State and Status Message" (Subtype=1 Format)

2.2.3.2.7.1.3.1 "SIL Supplement" Subfield in Target State and Status Messages

The "SIL Supplement" (Source Integrity Level Supplement) subfield is a 1-bit ("ME" bit 8, Message bit 40) field that **shall** define whether the reported SIL probability is based on a "per hour" probability or a "per sample" probability as defined in Table 2-46.

Table 2-46: "SIL Supplement" Subfield Encoding

Coding	Meaning
0	Probability of exceeding NIC radius of containment is based on "per hour"
1	Probability of exceeding NIC radius of containment is based on "per sample"

► **Per Hour:** The probability of the reported geometric position laying outside the NIC containment radius in any given hour without an alert or an alert longer than the allowable time-to-alert. The per hour representation will typically be used when the probability of exceeding the NIC is greater for the faulted versus fault-free Signal-in-Space case (When the Signal-in-Space fault rate is defined as hourly).

Note: *The probability of exceeding the integrity radius of containment for GNSS position sources are based on a per hour basis, as the NIC will be derived from the GNSS Horizontal Protection Level (HPL) which is based on a probability of* $1X10^{-7}$ *per hour.*

► **Per Sample:** The probability of a reported geometric position laying outside the NIC containment radius. The per sample representation will typically be used when the probability of exceeding the NIC is greater for the fault-free Signal-in-Space case, or when the position source does not depend on a Signal-in-Space.

Note: *The probability of exceeding the integrity radius of containment for IRU, DME/DME and DME/DME/LOC position sources may be based on a per sample basis.*

2.2.3.2.7.1.3.2 "Selected Altitude Type" Subfield in Target State and Status Messages

a. The "Selected Altitude Type" subfield is a 1-bit ("ME" bit 9, Message bit 41) field that **shall** be used to indicate the source of Selected Altitude data that is being used to encode "ME" bits 10 through 20 (Message bits 42 through 52). Encoding of the "Selected Altitude Type" **shall** be in accordance with Table 2-47.

Table 2-47: "Selected Altitude Type" Subfield Encoding

Coding	Meaning
0	Data being used to encode "ME" bits 10 through 20 is derived from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment.
1	Data being used to encode "ME" bits 10 through 20 is derived from the Flight Management System (FMS).

b. Whenever there is no valid MCP / FCU or FMS Selected Altitude data available, then the "Selected Altitude Type" subfield ("ME" bit 9, Message bit 41) **shall** be set to ZERO (0).

2.2.3.2.7.1.3.3 "MCP/FCU Selected Altitude or FMS Selected Altitude" Subfield in Target State and Status Messages

a. The "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield is an 11-bit ("ME" bits 10 through 20, Message bits 42 through 52) field that **shall** contain either MCP / FCU Selected Altitude or FMS Selected Altitude data in accordance with the following subparagraphs.

b. Whenever valid Selected Altitude data is available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, such data **shall** be used to encode "ME" bits 10 through 20 (Message bits 42 through 52) in accordance with Table 2-48. Use of MCP / FCU Selected Altitude **shall** then be declared in the "Selected Altitude Type" subfield as specified in Table 2-47.

c. Whenever valid Selected Altitude data is NOT available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, but valid Selected Altitude data is available from the Flight Management System (FMS), then the FMS Selected Altitude data **shall** be used to encode "ME" bits 10 through 20 (Message bits 42 through 52) in accordance with Table 2-48 provided in paragraph "d." Use of FMS Selected Altitude **shall** then be declared in the "Selected Altitude Type" subfield as specified in §2.2.3.2.7.1.3.2, Table 2-47.

d. Encoding of Selected Altitude data in "ME" bits 10 through 20 (Message bits 42 through 52) **shall** be in accordance with Table 2-48. Encoding of the data **shall** be rounded so as to preserve accuracy of the source data within ±½ LSB.

Table 2-48: "MCP/FCU Selected Altitude or FMS Selected Altitude" Subfield Encoding

Coding ("ME" bits 10 ---- 20)		**Meaning**
(Binary)	**(Decimal)**	
000 0000 0000	0	**NO Data *or* INVALID Data**
000 0000 0001	1	0 feet
000 0000 0010	2	32 feet
000 0000 0011	3	64 feet
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
111 1111 1110	2046	65440 feet
111 1111 1111	2047	65472 feet

e. Whenever there is NO valid MCP / FCU or FMS Selected Altitude data available, then the "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield ("ME" bits 10 through 20, Message bits 42 through 52) **shall** be set to ZERO (0) as indicated in Table 2-48.

2.2.3.2.7.1.3.4 "Barometric Pressure Setting (Minus 800 millibars)" Subfield in Target State and Status Messages

a. The "Barometric Pressure Setting (Minus 800 millibars)" subfield is a 9-bit ("ME" bits 21 through 29, Message bits 53 through 61) field that **shall** contain Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source.

b. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting **shall** be encoded in "ME" bits 21 through 29 (Message bits 53 through 61) in accordance with Table 2-49.

Table 2-49: "Barometric Pressure Setting (Minus 800 millibars)" Subfield Encoding

Coding ("ME" bits 21 ---- 29)		**Meaning**
(Binary)	**(Decimal)**	
0 0000 0000	0	**NO Data *or* INVALID Data**
0 0000 0001	1	0 millibars
0 0000 0010	2	0.8 millibars
0 0000 0011	3	1.6 millibars
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
1 1111 1110	510	407.2 millibars
1 1111 1111	511	408.0 millibars

c. Encoding of Barometric Pressure Setting data in "ME" bits 21 through 29 (Message bits 53 through 61) **shall** be rounded so as to preserve a reporting accuracy within ±½ LSB.

d. Whenever there is NO valid Barometric Pressure Setting data available, then the "Barometric Pressure Setting (Minus 800 millibars) subfield ("ME" bits 21 through 29, Message bits 53 through- 1) **shall** be set to ZERO (0) as indicated in Table 2-49.

e. Whenever the Barometric Pressure Setting data is greater than 1209.5 or less than 800 millibars, then the "Barometric Pressure Setting (Minus 800 millibars) subfield ("ME" bits 21 through 29, Message bits 53 through 61) **shall** be set to ZERO (0).

2.2.3.2.7.1.3.5 "Selected Heading Status" Subfield in Target State and Status Messages

The "Selected Heading Status" subfield is a 1-bit ("ME" bit 30, Message bit 62) field that **shall** be used to indicate the status of Selected Heading data that is being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) in accordance with Table 2-50.

Table 2-50: "Selected Heading Status" Subfield Encoding

Coding ("ME" bit 30)	**Meaning**
0	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is either **NOT** Available or is **INVALID**. See Table 2-52.
1	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is Available and is **VALID**. See Table 2-52.

2.2.3.2.7.1.3.6 "Selected Heading Sign" Subfield in Target State and Status Messages

The "Selected Heading Sign" subfield is a 1-bit ("ME" bit 31, Message bit 63) field that **shall** be used to indicate the arithmetic sign of Selected Heading data that is being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) in accordance with Table 2-51.

Table 2-51: "Selected Heading Sign" Subfield Encoding

Coding ("ME" bit 31)	**Meaning**
0	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is Positive in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is positive or Zero for all values that are less than 180 degrees). See Table 2-52.
1	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is Negative in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is ONE for all values that are greater than 180 degrees). See Table 2-52.

2.2.3.2.7.1.3.7 "Selected Heading" Subfield in Target State and Status Messages

a. The "Selected Heading" subfield is an 8-bit ("ME" bits 32 through 39, Message bits 64 through 71) field that **shall** contain Selected Heading data encoded in accordance with Table 2-52.

Table 2-52: "Selected Heading Status, Sign and Data" Subfields Encoding

"ME" Bit Coding			Meaning
30	31	32 -------- 39	
Status	**Sign**	**Data**	
0	0	0000 0000	**NO Data *or* INVALID Data**
1	0	0000 0000	0.0 degrees
1	0	0000 0001	0.703125 degrees
1	0	0000 0010	1.406250 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	0	1111 1111	179.296875 degrees
1	1	0000 0000	180.0 or -180.0 degrees
1	1	0000 0001	180.703125 or -179.296875 degrees
1	1	0000 0010	181.406250 or -178.593750 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	1	1000 0000	270.000 or -90.0000 degrees
1	1	1000 0001	270.703125 or -89.296875 degrees
1	1	1000 0010	271.406250 or -88.593750 degrees
1	1	1111 1110	358.593750 or -1.4062500 degrees
1	1	1111 1111	359.296875 or -0.7031250 degrees

b. Encoding of Selected Heading data in "ME" bits 31 through 39 (Message bits 63 through 71) **shall** be rounded so as to preserve accuracy of the source data within ±½ LSB.

c. Whenever there is NO valid Selected Heading data available, then the Selected Heading Status, Sign, and Data subfields ("ME" bits 30 through 39, Message bits 62 through 71) **shall** be set to ZERO (0) as indicated in Table 2-52.

2.2.3.2.7.1.3.8 "NAC_P" Subfield in Target State and Status Messages

The Navigation Accuracy Category for Position (NAC_P) subfield is a 4-bit ("ME" bits 40 through 43, Message bits 72 through 75) subfield of the Target State and Status Message that **shall** announce 95% accuracy limits for the horizontal position (and for some NAC_P values, the vertical position) that is being currently broadcast in Airborne Position and Surface Position Messages. Table 2-71 specifies the accuracy limits for each NAC_P value. If an update has not been received from an on-board data source for NAC_P within the past 5 seconds, then the NAC_P subfield **shall** be encoded as a value of ZERO (0) indicating "Unknown Accuracy."

Note: *The Navigation Accuracy Category for Position (NAC_P) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of accuracy for the intended use. See §2.1.2.13 of the ADS-B MASPS, RTCA DO-242A, for a fuller description of NAC_P.*

2.2.3.2.7.1.3.9 "NIC_{BARO}" Subfield in Target State and Status Messages

The "NIC_{BARO}" (Barometric Altitude Integrity Code) subfield is a 1-bit ("ME" bit 44, Message bit 76) field that **shall** be used to indicate whether or not the barometric pressure altitude being reported in the Airborne Position Message (§2.2.3.2.3) has been crosschecked against another source of pressure altitude. The "NIC_{BARO} " subfield **shall** be encoded in accordance with Table 2-73, as specified in the Aircraft Operational Status Message. If an update has not been received from an on-board data source for NIC_{BARO} within the past 5 seconds, then the NIC_{BARO} subfield **shall** be encoded as a value of ZERO (0).

2.2.3.2.7.1.3.10 "Source Integrity Level (SIL)" Subfield in Target State and Status Messages

The "SIL" (Source Integrity Level) subfield is a 2-bit ("ME" bits 45 and 46, Message bits 77 and 78) field that **shall** be used to define the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. The SIL will address the Signal-in-Space, if applicable, and will be the higher of the faulted or fault free probability of the Signal-In-Space causing the NIC radius of containment to be exceeded.

Note: *The faulted Signal-in-Space case will represent the highest probability for GNSS position sources while the fault free Signal-in-Space case will represent the highest probability for DME/DME or DME/DME/LOC position sources because the Signal-in-Space is monitored and for IRU position sources because there is no Signal-in-Space.*

The SIL probability can be defined as either "per sample" or "per hour" as defined in the SIL Supplement (SIL_{SUPP}) in §2.2.3.2.7.1.3.1.

The "SIL" subfield **shall** be encoded in accordance with Table 2-72, as specified in the Aircraft Operational Status Message. For installations where the SIL value is being dynamically updated, if an update has not been received from an on-board data source for SIL within the past 5 seconds, then the SIL subfield **shall** be encoded as a value of ZERO (0), indicating "Unknown."

Note: *The SIL and NIC should be set to unknown if the ADS-B position source does not supply an output certified to provide an indication of the integrity of the reported position (e.g., such as HPL from GNSS systems).*

2.2.3.2.7.1.3.11 "Status of MCP/FCU Mode Bits" Subfield in Target State and Status Messages

The "Status of MCP / FCU Mode Bits" subfield is a 1-bit ("ME" bit 47, Message bit 79) field that **shall** be used to indicate whether the mode bits ("ME" bits 48, 49, 50 and 52, Message bits 80, 81, 82 and 84) are actively being populated (e.g., set) in the Target State and Status Message in accordance with Table 2-53.

Table 2-53: "Status of MCP/FCU Mode Bits" Subfield Encoding

Coding ("ME" Bit 47)	Meaning
0	No Mode Information is being provided in "ME" bits 48, 49, 50 or 52 (Message bits 80, 81, 82, or 84)
1	Mode Information is deliberately being provided in "ME" bits 48, 49, 50 or 52 (Message bits 80, 81, 82, or 84)

If information is provided to the ADS-B Transmitting Subsystem to set either "ME" bit 48, 49, 50, or 52 (Message bit 80, 81, 82 or 84) to either "0" or "1," then bit 47 **shall** be set to ONE (1). Otherwise, bit 47 **shall** be set to ZERO (0).

2.2.3.2.7.1.3.12 "Autopilot Engaged" Subfield in Target State and Status Messages

The "Autopilot Engaged" subfield is a 1-bit ("ME" bit 48, Message bit 80) field that **shall** be used to indicate whether the autopilot system is engaged or not.

a. The ADS-B Transmitting Subsystem **shall** accept information from an appropriate interface that indicates whether or not the Autopilot is engaged.

b. The ADS-B Transmitting Subsystem **shall** set "ME" bit 48 (Message bit 80) in accordance with Table 2-54.

Table 2-54: "Autopilot Engaged" Subfield Encoding

Coding ("ME" Bit 48)	Meaning
0	Autopilot is NOT Engaged (e.g., not actively coupled and flying the aircraft)
1	Autopilot is Engaged (e.g., actively coupled and flying the aircraft)

2.2.3.2.7.1.3.13 "VNAV Mode Engaged" Subfield in Target State and Status Messages

The "VNAV Mode Engaged" subfield is a 1-bit ("ME" bit 49, Message bit 81) field that **shall** be used to indicate whether the Vertical Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** accept information from an appropriate interface that indicates whether or not the Vertical Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall** set "ME" bit 49 (Message bit 81) in accordance with Table 2-55.

Table 2-55: "VNAV Engaged" Subfield Encoding

Coding ("ME" Bit 49)	Meaning
0	VNAV Mode is NOT Active
1	VNAV Mode is Active

2.2.3.2.7.1.3.14 "Altitude Hold Mode" Subfield in Target State and Status Messages

The "Altitude Hold Mode" subfield is a 1-bit ("ME" bit 50, Message bit 82) field that **shall** be used to indicate whether the Altitude Hold Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** accept information from an appropriate interface that indicates whether or not the Altitude Hold Mode is active.

b. The ADS-B Transmitting Subsystem **shall** set "ME" bit 50 (Message bit 82) in accordance with Table 2-56.

Table 2-56: "Altitude Hold Mode" Subfield Encoding

Coding ("ME" Bit 50)	**Meaning**
0	Altitude Hold Mode is NOT Active
1	Altitude Hold Mode is Active

2.2.3.2.7.1.3.15 "Reserved for ADS-R Flag" Subfield in Target State and Status Messages

The "Reserved for ADS-R Flag" subfield is a 1-bit ("ME" bit 51, Message bit 83) field that **shall** be used as specified in §2.2.18.4.6.

2.2.3.2.7.1.3.16 "Approach Mode" Subfield in Target State and Status Messages

The "Approach Mode" subfield is a 1-bit ("ME" bit 52, Message bit 84) field that **shall** be used to indicate whether the Approach Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** accept information from an appropriate interface that indicates whether or not the Approach Mode is active.

b. The ADS-B Transmitting Subsystem **shall** set "ME" bit 52 (Message bit 84) in accordance with Table 2-57.

Table 2-57: "Approach Mode" Subfield Encoding

Coding ("ME" Bit 52)	**Meaning**
0	Approach Mode is NOT Active
1	Approach Mode is Active

2.2.3.2.7.1.3.17 "TCAS Operational" Subfield in Target State and Status Messages

The "TCAS Operational" subfield is a 1-bit ("ME" bit 53, Message bit 85) field that **shall** be used to indicate whether the TCAS System is Operational or not.

a. The ADS-B Transmitting Subsystem **shall** accept information from an appropriate interface that indicates whether or not the TCAS System is Operational.

b. The ADS-B Transmitting Subsystem **shall** set "ME" bit 53 (Message bit 85) in accordance with Table 2.2.3.2.7.1.3.17.

Table 2.2.3.2.7.1.3.17: "TCAS Operational" Subfield Encoding

Coding ("ME" Bit 53)	**Meaning**
0	TCAS System is NOT Operational
1	TCAS System is Operational

Note: *As a reference point, RTCA DO-181D Mode-S Transponders consider that the TCAS System is operational when "MB" bit 16 of Register 10_{16} is set to "ONE" (1). This occurs when the transponder / TCAS interface is operational and the transponder is receiving TCAS RI=2, 3 or 4. (Refer to RTCA DO-181D [EUROCAE ED-73C], Appendix B, Table B-3-16.*

2.2.3.2.7.1.3.18 "Reserved" Subfield in Target State and Status Messages

ME bits 54 through 56 (Message bits 86 through 88) of the Target State and Status Message are "Reserved" for future assignment and **shall** be set to ZERO (0) in this version of these MOPS.

2.2.3.2.7.1.4 Reserved for TYPE=29 and Subtype > 1 Message Formats

This section is reserved for future editions of these MOPS to specify additional Target State and Status Messages with the TYPE Code equal to 29 and the Subtype greater than ONE (1).

2.2.3.2.7.2 "Aircraft Operational Status" Messages

The "Aircraft Operational Status Message" is used to provide the current status of the aircraft. The format of the Aircraft Operational Status Message **shall** be as specified in Figure 2-11, while further definition of each of the subfields is provided in the subsequent paragraphs.

Aircraft Operational Status ADS-B Message "ME" Field Format														
MSG BIT #	33 - 37	38 - 40	41 - 52	53 - 56	57 - 72	73 - 75	76	77 - 80	81 - 82	83 - 84	85	86	87	88
"ME" BIT #	1 - 5	6 - 8	9 - 20	21 - 24	25 - 40	41 - 43	44	45 - 48	49 - 50	51 - 52	53	54	55	56
FIELD NAME	**TYPE=31 [5]**	**Subtype=0 [3]**	**Capability Class (CC) Codes [16]**		**Operational Mode (OM) Codes [16]**	**MOPS Version Number [3]**	**NIC Supp-A [1]**	**NAC_P [4]**	**GVA [2]**	**Source Integrity Level (SIL) [2]**	**NIC_{BARO} [1]**	**HRD [1]**	**SIL Supp [1]**	**Reserved [1]**
		Subtype=1 [3]	**CC Codes [12]**	**L/W Codes [4]**	**Operational Mode (OM) Codes [16]**				**Reserved [2]**		**TRK/HDG [1]**			
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB		MSB LSB	MSB LSB	MSB LSB				

Note: *Subfields that are relevant only for Airborne Participants are allocated to Subtype ZERO (binary 000), while those that pertain only to Surface Participants are allocated to Subtype ONE (binary 001).*

Figure 2-11: "Aircraft Operational Status" ADS-B Message "ME" Field Format

2.2.3.2.7.2.1 "TYPE" Code Subfield in Aircraft Operational Status Messages

The "TYPE" Code subfield was previously specified for the Airborne Position Message in §2.2.3.2.3.1 and remains the same for the Aircraft Operational Status Message that uses TYPE Code 31.

2.2.3.2.7.2.2 "Subtype" Code Subfield in Aircraft Operational Status Messages

The "Subtype" Code subfield is a 3-bit ("ME" bits 6 through 8, Message bits 38 through 40) subfield that **shall** be used to indicate various types of Aircraft Operational Status Messages as specified in Table 2-58.

Table 2-58: "Subtype" Code Subfield in Aircraft Operational Status Messages Encoding

Coding	Meaning
0	Message contains Aircraft Operational Status data as shown in Figure 2-11 for **Airborne** Participants
1	Message contains Aircraft Operational Status data as shown in Figure 2-11 for **Surface** Participants
2 - 7	Reserved

2.2.3.2.7.2.3 "CAPABILITY CLASS (CC)" Subfield in Aircraft Operational Status Messages

The Capability Codes (CC) subfield of the ADS-B Aircraft Operational Status Message **shall** occupy 16 bits in the "airborne" format of that message and 12 bits in the "surface" format of the message. In the airborne format (messages with TYPE=31, Subtype=0), the CC codes **shall** occupy "ME" bits 9 through 24 (Message bits 41 through 56). In the surface format (TYPE=31, Subtype=1), the CC codes **shall** occupy "ME" bits 9 through 20 (Message bits 41 through 52). The format of this subfield depends on the value of the Version Number subfield (§2.2.3.2.7.2.5). Moreover, for ADS-B Messages transmitted from a "Version 1" ADS-B Transmitting Subsystem, the CC format depends on whether the ADS-B Aircraft Operational Status Message Subtype field is has a value of 0 or 1.

If the Version Number subfield (§2.2.3.2.7.2.5) is ZERO (0), then the format of the CC subfield is as specified in the initial version of these MOPS (RTCA DO-260). This is summarized in Table 2-59.

Table 2-59: Capability Class (CC) Code Format in Version 0 Transmitting Subsystems

Msg Bit #	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
“ME” Bit #	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Content	0	0	Not-TCAS	CDTI	Reserved											

Notes for Table 2-59:

1. Not-TCAS = “TCAS/ACAS Not Installed Or Not Operational”
2. CDTI = “CDTI Traffic Display Capability”
3. Reserved = “Reserved for standardization in future versions of these MOPS”

If the Version Number subfield (§2.2.3.2.7.2.5) is TWO (2) (for ADS-B Transmitting Subsystems conformant to RTCA DO-260A), and the Subtype subfield is ZERO (0) (for Airborne Participants), then the format of the CC subfield **shall** be as specified in Table 2-60.

Table 2-60: Airborne Capability Class (CC) Code Format in Version 2 Transmitting Subsystems.

Msg Bit #	41	42	43	44	45	46	47	48	49	50	51	52 -- 56
“ME” Bit #	9	10	11	12	13	14	15	16	17	18	19	20 -- 24
Content	**Reserved** = 0,0		**TCAS Operational**	**1090ES IN**	**Reserved** = 0,0		**ARV**	**TS**	**TC**		**UAT IN**	**Reserved [6]**
	0,1		Reserved									
	1,0		Reserved									
	1,1		Reserved									

Notes for Table 2-60:

1. TCAS Operational = TCAS is Operational or Not Operational
2. 1090ES IN = Aircraft has ADS-B 1090ES Receive Capability
3. ARV = “ARV Report Capability”
4. TS = “TS Report Capability”
5. TC = “TC Report Capability Level”
6. UAT IN = Aircraft has ADS-B UAT Receive Capability
7. Reserved = “Reserved for standardization in future versions of these MOPS”

If the Version Number subfield (§2.2.3.2.7.2.5) is TWO (2) (for ADS-B Transmitting Subsystems conformant to RTCA DO-260B), and the Aircraft Operational Status Message Subtype subfield is ONE (1) (indicating Surface Participants), then the format of the CC subfield **shall** be as specified in Table 2-61.

Table 2-61: Surface Capability Class (CC) Code Format in Version 2 Transmitting Subsystems.

Msg Bit #	41	42	43	44	45	46	47	48	49 – 51	52
"ME" Bit #	9	10	11	12	13	14	15	16	17 – 19	20
Content	**Reserved** 0,0		**POA**	**1090ES IN**	**Reserved** = 0,0		**B2 Low**	**UAT IN**	**NAC_V [3]**	**NIC Supplement-C**
	0,1		Reserved							
	1,0		Reserved							
	1,1		Reserved							

Notes for Table 2-61:

1. POA = "Position Offset Applied"
2. 1090ES IN = Aircraft has ADS-B 1090ES Receive Capability
3. B2 Low = 1 if Class B2 Ground Vehicle is transmitting with less than 70 watts
4. UAT IN = Aircraft has ADS-B UAT Receive Capability
5. NAC_V = Navigation Accuracy Category for Velocity
6. NIC Supplement-C = NIC Supplement used on the Surface
7. Reserved = "Reserved for standardization in future versions of these MOPS"

If the Version Number subfield (§2.2.3.2.7.2.5) is TWO (2) (for ADS-B Transmitting Subsystems conformant to RTCA DO-260B), and an update has not been received from an on-board data source within the past 5 seconds for any data element of the Capability Class subfield, then the data associated with that data element **shall** be considered invalid and so reflected in the encoding of that message element to reflect "No Capability" or "Unknown Capability."

2.2.3.2.7.2.3.1 "Reserved" CC Code Subfields in Aircraft Operational Status Message

Within the Capability Class subfield, "ME" bits 9-10, 13-14, and 20-24 (Message bits 41-42, 45-46 and 52-56) **shall** be reserved for setting by a future version of these MOPS. ADS-B equipment conforming to this version of these MOPS (RTCA DO-260B) **shall** set these reserved bits to ALL ZEROs.

Note: *Future versions of these MOPS may define values other than zero for these reserved bits.*

2.2.3.2.7.2.3.2 "TCAS Operational" CC Code Subfield in Aircraft Operational Status Messages

The "TCAS Operational" subfield ("ME" bit 11, Message bit 43) of the CC Codes subfield in ADS-B Aircraft Operational Status Messages (TYPE=31, SUBTYPE=0, for airborne participants) **shall** be used to indicate whether the TCAS System is Operational or not, and remains as defined for use in the Target State and Status Message (§2.2.3.2.7.1.3.17), with the encoding as specified in Table 2.2.3.2.7.1.3.17.

2.2.3.2.7.2.3.3 "1090ES IN" CC Code Subfield in Aircraft Operational Status Messages

The CC Code subfield for "1090ES IN" in Aircraft Operational Status Messages (TYPE=31, Subtype=0 or 1) is a 1-bit field ("ME" bit 12, Message bit 44) that **shall** be set to ONE (1) as specified in Table 2-63 if the transmitting aircraft has the capability to receive ADS-B 1090ES Messages. Otherwise, this CC code subfield **shall** be set to ZERO (0).

Table 2-63: Encoding of "1090ES IN" CC Subfield in Aircraft Operational Status Messages

"1090ES IN" CC Code Encoding	Meaning
0	No Capability to Receive ADS-B 1090ES Messages
1	Aircraft has the Capability to Receive ADS-B 1090ES Messages

2.2.3.2.7.2.3.4 "ARV Report Capability" CC Code Subfield in Aircraft Operational Status Messages

The "ARV Report Capability" subfield of the CC Codes subfield is a one-bit Boolean flag that **shall** be encoded as specified in Table 2-64.

Table 2-64: ARV Report Capability Encoding.

Coding	Meaning
0	No capability for sending messages to support Air Referenced Velocity Reports
1	Capability of sending messages to support Air-Referenced Velocity Reports.

2.2.3.2.7.2.3.5 "TS Report Capability" CC Code Subfield in Aircraft Operational Status Messages

The "Target State (TS) Report Capability" subfield of the CC Codes subfield is a one-bit Boolean flag in the "airborne" format of the Aircraft Operational Status Message (TYPE=31, Subtype=0) that **shall** be encoded as specified in Table 2-65.

Table 2-65: TS Report Capability Encoding.

Coding	Meaning
0	No capability for sending messages to support Target State Reports
1	Capability of sending messages to support Target State Reports.

2.2.3.2.7.2.3.6 "TC Report Capability" CC Code Subfield in Aircraft Operational Status Messages

The "Trajectory Change (TC) Report Capability" subfield of the CC Code subfield is a two-bit ("ME" bits 17 and 18) subfield in the "airborne" format of the Aircraft Operational Status Message (TYPE=31, Subtype=0) and is defined in the ADS-B MASPS (RTCA DO-242A) as specified in Table 2-66. For these MOPS the subfield **shall** be set to ZERO (binary 00).

Table 2-66: TC Report Capability Encoding

Coding		Meaning
(Binary)	(Decimal)	
00	0	No capability for sending messages to support Trajectory Change Reports
01	1	Capability of sending messages to support TC+0 Report only.
10	2	Capability of sending information for multiple TC reports.
11	3	(Reserved for future use.)

2.2.3.2.7.2.3.7 "Position Offset Applied" CC Code Subfield in Surface Aircraft Operational Status Messages

The "Position Offset Applied" (POA) subfield of the CC Code subfield of the "surface" format Aircraft Operational Status Message (TYPE=31, Subtype=1) is a one-bit Boolean flag that the ADS-B Transmitting Subsystem **shall** set to ONE as specified in Table 2-67 if the position that it is transmitted in the ADS-B Surface Position Message (§2.2.3.2.4) is known to be the position of the ADS-B participant's ADS-B Position Reference Point (RTCA DO-242A, §3.4.4.9.7) rather than, for example, the position of the antenna of the navigation receiver. Otherwise, the ADS-B Transmitting Subsystem **shall** set this flag to ZERO.

Table 2-67: Position Offset Applied (POA) Encoding

Coding	Meaning
0	The position transmitted in the Surface Position Message is not known to be referenced to the ADS-B Position Reference Point of the A/V
1	The position transmitted in the Surface Position Message is known to be referenced to the ADS-B Position Reference Point of the A/V

2.2.3.2.7.2.3.8 "B2 Low" CC Code Subfield in Surface Aircraft Operational Status Messages

The "B2 Low" subfield ("ME" bit 15) of the CC Code subfield in the "surface" version of the Aircraft Operational Status Message (TYPE=31, Subtype=1) is a one-bit Boolean flag that the ADS-B Transmitting Subsystem **shall** set to ONE (1) if the Transmitting Subsystem is a Non-Transponder-Based Transmitting Subsystem on a Ground Vehicle that meets the requirements of Class B2, except that it transmits with less than 70 watts of power. Otherwise, this bit **shall** be set to ZERO (0).

Note: *Setting the "B2 Low" CC Code bit indicates to airborne participants that any transmissions from that surface participant are at lower than the minimum 70 watts power required of Class B2 participants by these MOPS.*

2.2.3.2.7.2.3.9 "NAC_V" CC Code Subfield in Surface Aircraft Operational Status Messages

The requirements for establishing the values for the Navigation Accuracy Category for Velocity (NAC_V) are stated in §2.2.3.2.6.1.5 in conjunction with the Airborne Velocity Messages. The NAC_V subfield **shall** be provided in "ME" bits 17 through 19 (Message bits 49 through 51) of the Surface Aircraft Operational Status Message.

2.2.3.2.7.2.3.10 "UAT IN" CC Code Subfield in Aircraft Operational Status Messages

The "UAT IN" CC Code subfield ("ME" bit 19, Message bit 51, TYPE=31, Subtype=0, for airborne participants AND "ME" Bit 16, Message bit 48, TYPE=31, Subtype=1 for surface participants) in ADS-B Aircraft Operational Status Messages denotes whether the aircraft is equipped with the capability to receive ADS-B UAT Messages. The coding of "UAT IN" CC Code subfield **shall** be as specified in Table 2.2.3.2.7.2.3.10.

Table 2.2.3.2.7.2.3.10: Encoding of "UAT IN" CC Subfield in Aircraft Operational Status Messages.

"UAT IN" CC Code Encoding	Meaning
0	No Capability to Receive ADS-B UAT Messages
1	Aircraft has the Capability to Receive ADS-B UAT Messages

The "UAT IN" CC Code in Aircraft Operational Status Messages **shall** be set to ZERO (0) in Aircraft Operational Status Messages if the aircraft is NOT fitted with the capability to receive ADS-B UAT Messages. The "UAT IN" CC Code Subfield in Aircraft Operational Status Messages **shall** be set to ONE (1) if the aircraft has the capability to receive ADS-B UAT Messages.

Note: *If the aircraft is fitted with ADS-B UAT receive equipment but such equipment is not functional, then the encoding should be set to "ZERO" (0), e.g., the same as if the aircraft were NOT fitted with the receive capability.*

2.2.3.2.7.2.3.11 "NIC Supplement-C" CC Code Subfield in Aircraft Operational Status Messages

The NIC Supplement-C subfield in the Aircraft Operational Status Message is a one-bit subfield ("ME" bit 20, Message bit 52) that, together with the TYPE subfield in Surface Position Messages and the NIC Supplement-A in the Operational Status Message ("ME" Bit 44, Message Bit 76), **shall** be used to encode the Navigation Integrity Category (NIC) of the transmitting ADS-B participant.

If an update has not been received from an on-board data source for the determination of the NIC value within the past 5 seconds, then the NIC Supplement subfield **shall** be encoded to indicate the larger Radius of Containment (R_C).

Table 2-70 lists the possible NIC codes and the values of the TYPE subfield of the Airborne and Surface Position Messages, and of the NIC Supplement subfields that **shall** be used to encode those NIC codes in messages on the 1090 MHz ADS-B data link.

2.2.3.2.7.2.4 "OPERATIONAL MODE (OM)" Subfield in Aircraft Operational Status Messages

The "Operational Mode (OM)" subfield is a 16-bit subfield ("ME" bits 25 through 40, Message bits 57 through 72) that **shall** indicate Operational Modes that are active on board the A/V in which the ADS-B Transmitting Subsystem resides. The format of the OM subfield in Aircraft Operational Status Messages, with Subtype=0 for airborne participants **shall** be as specified in Table 2-68A. The format of the OM subfield in Aircraft Operational Status Messages, with Subtype=1 for surface participants shall be as specified in Table 2-68B.

Table 2-68A: Airborne Operational Mode (OM) Subfield Format

Msg Bit #	57	58	59	60	61	62	63 -- 64	65 -- 72
"ME" Bit #	25	26	27	28	29	30	31 – 32	33 – 40
OM Format	0 0		**TCAS RA Active [1]**	**IDENT Switch Active [1]**	**Reserved for Receiving ATC Services [1]**	**Single Antenna Flag [1]**	**System Design Assurance [2]**	**Reserved [8]**
	0 1		Reserved					
	1 0		Reserved					
	1 1		Reserved					

Table 2-68B: Surface Operational Mode (OM) Subfield Format

Msg Bit #	57	58	59	60	61	62	63 -- 64	65 -- 72
"ME" Bit #	25	26	27	28	29	30	31 – 32	33 – 40
OM Format	0 0		**TCAS RA Active [1]**	**IDENT Switch Active [1]**	**Reserved for Receiving ATC Services [1]**	**Single Antenna Flag [1]**	**System Design Assurance [2]**	**GPS Antenna Offset [8]**
	0 1		Reserved					
	1 0		Reserved					
	1 1		Reserved					

2.2.3.2.7.2.4.1 OM Subfield Format Code in Aircraft Operational Status Messages

The first two bits of the OM subfield ("ME" bits 25 and 26) **shall** be reserved for selecting one of up to four OM subfield formats. For this version of these MOPS (DO-260B), the OM subfield format code **shall** be set to ZERO (binary 00).

2.2.3.2.7.2.4.2 "TCAS/ACAS Resolution Advisory Active" OM Code Subfield in Aircraft Operational Status Message

The "TCAS/ACAS Resolution Advisory Active" (RA Active) Operational Mode Code is a one-bit subfield ("ME" bit 27, Message bit 59) of the OM subfield in Aircraft Operational Status Messages (TYPE=31, Subtype=0 or 1). The ADS-B Transmitting Subsystem **shall** set this code to ZERO (0) so long as a TCAS II or ACAS Resolution Advisory is known **not** to be in effect (i.e., an update has been received within the last 2 seconds that indicates a "TCAS/ACAS Resolution Advisory is **not** Active"); otherwise, it **shall** set this OM code to ONE (1).

2.2.3.2.7.2.4.3 "IDENT Switch Active" OM Code Subfield in Aircraft Operational Status Message

The "IDENT Switch Active" Operational Mode code is a one-bit subfield ("ME" bit 28, message bit 60) of the OM Code subfield in Aircraft Operational Status Messages. Initially, the "IDENT Switch Active" OM Code **shall** be set to ZERO. Upon activation of the IDENT switch, the ADS-B Transmitting Subsystem **shall** set this code to ONE for a period of 18 ± 1 seconds; thereafter, the ADS-B Transmitting Subsystem **shall** set this OM Code to ZERO.

Note: *The requirement for an interface by which the ADS-B Transmitting Subsystem may be informed when the IDENT switch is active is given in §2.2.5.1.30.*

2.2.3.2.7.2.4.4 Reserved for "Receiving ATC Services" OM Code Subfield in Aircraft Operational Status Message

"ME" bit 29, Message bit 61 of the OM Code subfield in Aircraft Operational Status Messages **shall** be reserved for the "Receiving ATC Services" Operational Mode Code. If implemented into future versions of these MOPS, an ADS-B Transmitting Subsystem would set this OM Code to ONE when the ADS-B Transmitting Subsystem is Receiving ATC Services, as indicated by an update having been received via an appropriate interface on board the transmitting aircraft within the past 5 seconds. Otherwise, in this version of these MOPS, this OM Code bit **shall** be set to ZERO.

Note: *The requirement for an interface by which the ADS-B Transmitting Subsystem may be informed when the aircraft is receiving ATC services is given in §2.2.5.1.31.*

2.2.3.2.7.2.4.5 "Single Antenna Flag" OM Code Subfield in Aircraft Operational Status Messages

The "Single Antenna" subfield is a 1-bit ("ME" bit 30, Message bit 62) field that **shall** be used to indicate that the ADS-B Transmitting Subsystem is operating with a single antenna. The following conventions **shall** apply both to Transponder-Based and Stand Alone ADS-B Transmitting Subsystems:

a. Non-Diversity, i.e., those transmitting functions that use only one antenna, **shall** set the Single Antenna subfield to "ONE" at all times.

b. Diversity, i.e., those transmitting functions designed to use two antennas, **shall** set the Single Antenna subfield to "ZERO" at all times that both antenna channels are functional.

At any time that the diversity configuration cannot guarantee that both antenna channels are functional, then the Single Antenna subfield **shall** be set to "ONE."

Note: *Certain applications may require confirmation that each participant has functioning antenna diversity for providing adequate surveillance coverage*.

2.2.3.2.7.2.4.6 "System Design Assurance" OM Code Subfield in Aircraft Operational Status Messages

The "System Design Assurance" (SDA) subfield is a 2-bit ("ME" bits 31 – 32, Message bits 63 – 64) field that **shall** define the failure condition that the ADS-B system is designed to support as defined in Table 2.2.3.2.7.2.4.6.

The supported failure condition will indicate the probability of an ADS-B system fault causing false or misleading information to be transmitted. The definitions and probabilities associated with the supported failure effect are defined in AC 25.1309-1A, AC 23-1309-1C, and AC 29-2C. All relevant systems attributes should be considered including software and complex hardware in accordance with RTCA DO-178B (EUROCAE ED-12B) or RTCA DO-254 (EUROCAE ED-80).

The ADS-B system includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data transmitted by the ADS-B system.

Table 2.2.3.2.7.2.4.6: "System Design Assurance" OM Subfield in Aircraft Operational Status Messages

SDA Value		Supported Failure Condition Note 2	Probability of Undetected Fault causing transmission of False or Misleading Information Note 3,4	Software & Hardware Design Assurance Level Note 1,3
(decimal)	(binary)			
0	00	Unknown/ No safety effect	$> 1X10^{-3}$ per flight hour or Unknown	N/A
1	01	Minor	$\leq 1X10^{-3}$ per flight hour	D
2	10	Major	$\leq 1X10^{-5}$ per flight hour	C
3	11	Hazardous	$\leq 1X10^{-7}$ per flight hour	B

Notes:

1. *Software Design Assurance per RTCA DO-178B (EUROCAE ED-12B). Airborne Electronic Hardware Design Assurance per RTCA DO-254 (EUROCAE ED-80).*
2. *Supported Failure Classification defined in AC-23.1309-1C, AC-25.1309-1A, and AC 29-2C.*
3. *Because the broadcast position can be used by any other ADS-B equipped aircraft or by ATC, the provisions in AC 23-1309-1C that allow reduction in failure probabilities and design assurance level for aircraft under 6,000 pounds do not apply.*
4. *Includes probability of transmitting false or misleading latitude, longitude, velocity, or associated accuracy and integrity metrics.*

2.2.3.2.7.2.4.7 "GPS Antenna Offset" OM Code Subfield in Aircraft Operational Status Messages

The "GPS Antenna Offset" subfield is an 8-bit ("ME" bits 33 – 40, Message bits 65 – 72) field in the OM Code Subfield of surface format Aircraft Operational Status Messages that **shall** define the position of the GPS antenna in accordance with the following when Position Offset Applied (§2.2.3.2.7.2.3.7) is set to ZERO (0).

a. Lateral Axis GPS Antenna Offset:

"ME" bits 33 through 35 (Message bits 65 through 67) **shall** be used to encode the lateral distance of the GPS Antenna from the longitudinal axis (Roll) axis of the aircraft. Encoding **shall** be established in accordance with Table 2.2.3.2.7.2.4.7A.

Table 2.2.3.2.7.2.4.7A: Lateral Axis GPS Antenna Offset Encoding

<table>
<tr><th colspan="3">"ME" Bit
(Message Bit)</th><th colspan="2" rowspan="3">GPS Antenna Offset
Along Lateral (Pitch) Axis
Left or Right of Longitudinal (Roll) Axis</th></tr>
<tr><th>33
(65)</th><th>34
(66)</th><th>35
(67)</th></tr>
<tr><th rowspan="2">0 = left
1 = right</th><th colspan="2">Encoding</th></tr>
<tr><th>Bit 1</th><th>Bit 0</th><th>Direction</th><th>(meters)</th></tr>
<tr><td rowspan="4">0</td><td>0</td><td>0</td><td rowspan="4">LEFT</td><td>0 or NO DATA</td></tr>
<tr><td>0</td><td>1</td><td>2</td></tr>
<tr><td>1</td><td>0</td><td>4</td></tr>
<tr><td>1</td><td>1</td><td>6</td></tr>
<tr><td rowspan="4">1</td><td>0</td><td>0</td><td rowspan="4">RIGHT</td><td>0 or NO DATA</td></tr>
<tr><td>0</td><td>1</td><td>2</td></tr>
<tr><td>1</td><td>0</td><td>4</td></tr>
<tr><td>1</td><td>1</td><td>6</td></tr>
<tr><td colspan="5">Notes:
1. Left means toward the left wing tip moving from the longitudinal center line of the aircraft.
2. Right means toward the right wing tip moving from the longitudinal center line of the aircraft.
3. Maximum distance left or right of aircraft longitudinal (roll) axis is 6 meters or 19.685 feet.</td></tr>
</table>

b. Longitudinal Axis GPS Antenna Offset:

"ME" bits 36 through 40 (Message bits 68 through 72) **shall** be used to encode the longitudinal distance of the GPS Antenna from the NOSE of the aircraft. Encoding **shall** be established in accordance with Table 2.2.3.2.7.2.4.7B.

Table 2.2.3.2.7.2.4.7B: Longitudinal Axis GPS Antenna Offset Encoding

Longitudinal Axis GPS Antenna Offset Encoding					
"ME" Bit (Message Bit)					**GPS Antenna Offset Along Longitudinal (Roll) Axis Aft From Aircraft Nose**
36 (68)	**37** (69)	**38** (70)	**39** (71)	**40** (72)	
Encoding					
Bit 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**(meters)**
0	0	0	0	0	0 ***or*** **NO DATA**
0	0	0	0	1	2
0	0	0	1	0	4
0	0	0	1	1	6
0	0	1	0	0	8
*	*	*	*	*	***
*	*	*	*	*	***
*	*	*	*	*	***
1	1	1	1	1	62
Note: *Maximum distance aft from aircraft nose is 62 meters or 203.412 feet.*					

When Position Offset Applied (§2.2.3.2.7.2.3.7) is set to ONE (1), the GPS Antenna Offset subfield **shall** be set to ALL ZEROs (0).

Note: *When Position Offset Applied (§2.2.3.2.7.2.3.7) is set to ONE (1), it means that the GPS antenna position has already been compensated for in the reported latitude and longitude position subfields of the Surface Position Message. Ensuring that the GPS Antenna subfield is set to ZERO in this case ensures that the offset compensation is not performed again by a receiving application.*

2.2.3.2.7.2.4.8 "Reserved" OM Code Subfield in Aircraft Operational Status Messages

"Reserved" bits, ("ME" bits 33 through 40, Message bits 65 through 72) in the OM Code Subfield of Surface format Aircraft Operational Status Messages are reserved for future assignment. Until such future assignment, these bits **shall** be set to "ZERO" (0).

2.2.3.2.7.2.5 ADS-B "Version Number" Subfield in Aircraft Operational Status Message

The ADS-B "Version Number" (VN) subfield is a 3-bit ("ME" bits 41 through 43, Message bits 73 through 75) field that **shall** be used to indicate the Version Number of the formats and protocols in use on the aircraft installation. Encoding of the ADS-B Version Number subfield **shall** be as shown in Table 2-69. Airborne ADS-B systems conformant to the initial version of the 1090 MHz ADS-B MOPS (RTCA DO-260) do not broadcast an explicit ADS-B Version Number. Therefore, ADS-B Receiving Subsystems conformant with this version of the 1090 MHz MOPS (RTCA DO-260B) **shall** initially assume a Version Number of ZERO (binary 000), until a received ADS-B Version Number data indicates otherwise.

Table 2-69: Version Number Subfield Encoding

Coding		Meaning
(Binary)	(Decimal)	
000	0	Conformant to DO-260 and DO-242
001	1	Conformant to DO-260A and DO-242A
010	2	Conformant to DO-260B and DO-242B
011 – 111	3 – 7	Reserved

2.2.3.2.7.2.6 "NIC Supplement-A" Subfield in Aircraft Operational Status Messages

The NIC Supplement-A subfield in the Aircraft Operational Status Message is a one-bit subfield ("ME" bit 44, Message bit 76) that, together with the TYPE subfield in Airborne Position and Surface Position Messages, **shall** be used to encode the Navigation Integrity Category (NIC) of the transmitting ADS-B participant. In ADS-B Transmitting Subsystems with Version Number=2, or later, the NIC Supplement-B is also broadcast in the Airborne Position Message (§2.2.3.2.3.3).

Note: *The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of integrity for the intended use. See §2.1.2.12 of RTCA DO-242A, the ADS-B MASPS, for a fuller description of the Navigation Integrity Category.*

If an update has not been received from an on-board data source for the determination of the NIC value within the past 5 seconds, then the NIC Supplement subfield **shall** be encoded to indicate the larger Radius of Containment (R_C).

Table 2-70 lists the possible NIC codes and the values of the TYPE subfield of the Airborne and Surface Position Messages, and of the NIC Supplement subfield that **shall** be used to encode those NIC codes in messages on the 1090 MHz ADS-B data link.

Table 2-70: Navigation Integrity Category (NIC) Encoding.

NIC Value	Radius of Containment (R_C)	Airborne			Surface		
		Airborne Position TYPE Code	NIC Supplement Codes		Surface Position TYPE Code	NIC Supplement Codes	
			A	B		A	C
0	R_C unknown	0, 18 or 22	0	0	0, 8	0	0
1	R_C < 20 NM (37.04 km)	17	0	0	N/A	N/A	N/A
2	R_C < 8 NM (14.816 km)	16	0	0	N/A	N/A	N/A
3	R_C < 4 NM (7.408 km)	16	1	1	N/A	N/A	N/A
4	R_C < 2 NM (3.704 km)	15	0	0	N/A	N/A	N/A
5	R_C < 1 NM (1852 m)	14	0	0	N/A	N/A	N/A
6	R_C < 0.6 NM (1111.2 m)	13	1	1	8	0	1
	R_C < 0.5 NM (926 m)	13	0	0	N/A	N/A	N/A
	R_C < 0.3 NM (555.6 m)	13	0	1	8	1	0
7	R_C < 0.2 NM (370.4 m)	12	0	0	8	1	1
8	R_C < 0.1 NM (185.2 m)	11	0	0	7	0	0
9	R_C < 75m	11	1	1	7	1	0
10	R_C < 25m	10 or 21	0	0	6	0	0
11	R_C < 7.5m	9 or 20	0	0	5	0	0
12	Reserved						
13	Reserved						
14	Reserved						
15	Reserved						

Notes:

1. *"N/A" means "This NIC value is not available in the ADS-B Surface Position Message formats."*

2. *NIC Supplement-A is broadcast in the Aircraft Operational Status Message, "ME" bit 44 (Message bit 76, see Figure 2-11). NIC Supplement-B is broadcast in the Airborne Position Message, "ME" bit 8 (Message bit 40, see Figure 2-3). NIC Supplement-C is broadcast in the Surface Capability Class (CC) Code Subfield of the Aircraft Operational Status Message, "ME" bit 20 (Message bit 52, see Table 2-61).*

2.2.3.2.7.2.7 "Navigation Accuracy Category for Position (NAC_P)" Subfield in Aircraft Operational Status Messages

The Navigation Accuracy Category for Position (NAC_P) is a 4-bit subfield of the ADS-B Aircraft Operational Status Message ("ME" bits 45 to 48, Message bits 77 to 80) that **shall** announce 95% accuracy limits for the horizontal position (and for some NAC_P values, the vertical position) that is being currently broadcast in airborne position and surface position messages. Table 2-71 specifies the accuracy limits for each NAC_P value. If an update has not been received from an on-board data source for NAC_P within the past 5 seconds, then the NAC_P subfield **shall** be encoded as a value of ZERO (0) indicating "Unknown Accuracy."

Note: *The Navigation Accuracy Category for Position (NAC_P) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of accuracy for the intended use. See §2.1.2.13 of the ADS-B MASPS, RTCA DO-242A, for a fuller description of NAC_P.*

Table 2-71: Navigation Accuracy Category for Position (NAC_P) Encoding

Coding (Binary)	(Decimal)	95% Horizontal and Vertical Accuracy Bounds (EPU)	Comment	Notes
0000	0	EPU ≥ 18.52 km (≥10 NM)	Unknown accuracy	1
0001	1	EPU < 18.52 km (10 NM)	RNP-10 accuracy	1, 3
0010	2	EPU < 7.408 km (4 NM)	RNP-4 accuracy	1, 3
0011	3	EPU < 3.704 km (2 NM)	RNP-2 accuracy	1, 3
0100	4	EPU < 1852 m (1 NM)	RNP-1 accuracy	1, 3
0101	5	EPU < 926 m (0.5 NM)	RNP-0.5 accuracy	1, 3
0110	6	EPU < 555.6 m (0.3 NM)	RNP-0.3 accuracy	1, 3
0111	7	EPU < 185.2 m (0.1 NM)	RNP-0.1 accuracy	1, 3
1000	8	EPU < 92.6 m (0.05 NM)	e.g., GPS (with SA on)	1
1001	9	EPU < 30 m	e.g., GPS (SA off)	1, 2, 4
1010	10	EPU < 10 m	e.g., WAAS	1, 2, 4
1011	11	EPU < 3 m	e.g., LAAS	1, 2, 4
1100	12	Reserved		
1101	13	Reserved		
1110	14	Reserved		
1111	15	Reserved		

Notes for Table 2-71:

1. *The Estimated Position Uncertainty (EPU) used in the table is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position lying outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

2. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

2.2.3.2.7.2.8 "Geometric Vertical Accuracy (GVA)" Subfield in Aircraft Operational Status Messages

The "Geometric Vertical Accuracy (GVA)" subfield of Subtype=0 Aircraft Operational Status Message is a 2-bit field ("ME" bits 49-50, Message bits 81-82) defined in Table 2.2.3.2.7.2.8. The GVA field **shall** be set by using the Vertical Figure of Merit (VFOM) (95%) from the GNSS position source used to encode the geometric altitude field in the Airborne Position Message.

Table 2.2.3.2.7.2.8: Encoding of the Geometric Vertical Accuracy (GVA) Subfield in Aircraft Operational Status Messages

GVA Encoding (decimal)	Meaning (meters)
0	Unknown or > 45 meters
1	≤ 45 meters
2	Reserved
3	Reserved

Note: *For the purposes of these MOPS (RTCA DO-260B) values for 0 and 1 are encoded. Decoding values for 2 and 3 should be treated as < 45 meters until future versions of these MOPS redefine the values.*

2.2.3.2.7.2.9 "Source Integrity Level (SIL)" Subfield in Aircraft Operational Status Messages

The "SIL" (Source Integrity Level) subfield is a 2-bit ("ME" bits 45 and 46, Message bits 77 and 78) field that **shall** be used to define the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. The SIL will address the Signal-in-Space, if applicable, and will be the higher of the faulted or fault free probability of the Signal-In-Space causing the NIC radius of containment to be exceeded.

Note: *The faulted Signal-in-Space case will represent the highest probability for GNSS position sources while the fault free Signal-in-Space case will represent the highest probability for DME/DME or DME/DME/LOC position sources because the Signal-in-Space is monitored and for IRU position sources because there is no Signal-in-Space.*

The SIL probability can be defined as either "per sample" or "per hour" as defined in the SIL Supplement (SIL_{SUPP}) in §2.2.3.2.7.1.3.1.

The "SIL" subfield **shall** be encoded in accordance with Table 2-72. For installations where the SIL value is being dynamically updated, if an update has not been received from an on-board data source for SIL within the past 5 seconds, then the SIL subfield **shall** be encoded as a value of ZERO (0), indicating "Unknown."

Note: *The SIL and NIC should be set to unknown if the ADS-B position source does not supply an output certified to provide an indication of the integrity of the reported position (e.g., such as HPL from GNSS systems).*

Table 2-72: "SIL" Subfield Encoding

SIL Coding (Binary)	SIL Coding (Decimal)	Probability of Exceeding the NIC Containment Radius (R_C)
00	0	Unknown or $> 1 \times 10^{-3}$ per flight hour or per sample
01	1	$\leq 1 \times 10^{-3}$ per flight hour or per sample
10	2	$\leq 1 \times 10^{-5}$ per flight hour or per sample
11	3	$\leq 1 \times 10^{-7}$ per flight hour or per sample

Notes:

1. *The RTCA DO-242 definition of SIL has been updated in this version of these MOPS. These updates will be incorporated in §2.1.2.15 of the ADS-B MASPS, RTCA DO-242B.*

2. *Implementers should not arbitrarily set the SIL to ZERO (0) just because SIL is not provided by the position source. Implementers should perform an off-line analysis of the installed position source to determine the appropriate SIL.*

2.2.3.2.7.2.10 "Barometric Altitude Integrity Code (NIC_{BARO}) Subfield in Aircraft Operational Status Messages

The "NIC_{BARO}" (Barometric Altitude Integrity Code) is a 1-bit subfield of "Subtype 0" ADS-B Aircraft Operational Status Messages ("ME" bit 53, Message bit 85) that **shall** be used to indicate whether or not the barometric pressure altitude being reported in the Airborne Position Message (§2.2.3.2.3) has been cross-checked against another source of pressure altitude. The "NIC_{BARO} " subfield **shall** be encoded in accordance with Table 2-73. If an update has not been received from an on-board data source for NIC_{BARO} within the past 5 seconds, then the NIC_{BARO} subfield **shall** be encoded as a value of ZERO (0).

Table 2-73: "NIC_{BARO}" Subfield Encoding

Coding	Meaning
0	The barometric altitude that is being reported in the Airborne Position Message is based on a Gilham coded input that has not been cross-checked against another source of pressure altitude
1	The barometric altitude that is being reported in the Airborne Position Message is either based on a Gilham code input that has been cross-checked against another source of pressure altitude and verified as being consistent, or is based on a non-Gilham coded source

Notes:

1. *The NIC value itself is conveyed within the ADS-B Position Message.*

2. *The NIC_{BARO} subfield provides a method of indicating a level of data integrity for aircraft installed with Gilham encoding barometric altitude sources. Because of the potential of an undetected error when using a Gilham encoded altitude source, a comparison will be performed with a second source and only if the two sources agree will the NIC_{BARO} subfield be set to a value of ONE (1). For other barometric altitude sources (Synchro or DADS) the integrity of the data is indicated with a validity flag or SSM. No additional checks or comparisons are necessary. For these sources the NIC_{BARO} subfield will be set to a value of ONE (1) whenever the barometric altitude is valid.*

3. *The use of Gilham type altimeters is strongly discouraged because of the potential for undetected altitude errors.*

2.2.3.2.7.2.11 "Aircraft/Vehicle Length and Width Code" Subfield in Aircraft Operational Status Messages

The Aircraft/Vehicle (A/V) Length and Width Code Subfield is a four-bit field ("ME" bits 21 to 24, Message bits 53 to 56) of the Aircraft Operational Status Messages (Subtype=1, for Surface Participants). This field **shall** describe the amount of space that an aircraft or ground vehicle occupies. The A/V Length and Width Code is based on the actual dimensions of the transmitting aircraft or surface vehicle as specified in Table 2-74. Once the actual Length and Width of the A/V has been determined, each A/V **shall** be assigned the smallest A/V Length and Width Code from Table 2-74 for which the actual length is less than or equal to the upper bound length for that Length/Width Code, and for which the actual width is less than or equal to the upper bound width for that Length/Width Code.

Note: *For example, consider a powered glider with overall length of 24 m and wingspan of 50 m. Normally, an aircraft of that length would be in length category 1 (that is, have a length code of 1). But since the wingspan exceeds 34 m, it does not qualify for even the "wide" subcategory (width code = 1) of length category 1. Such an aircraft would be assigned length code = 4 and width code = 1, meaning "length less than 55 m and width less than 52 m."*

Table 2-74: "Aircraft/Vehicle Length and Width Code" Encoding

A/V - L/W Code (Decimal)	Length Code			Width Code	Upper-Bound Length and Width for Each Length/Width Code	
	ME Bit 21	ME Bit 22	ME Bit 23	ME Bit 24	Length (meters)	Width (meters)
0	0	0	0	0	No Data or Unknown	
1	0	0	0	1	15	23
2	0	0	1	0	25	28.5
3				1		34
4	0	1	0	0	35	33
5				1		38
6	0	1	1	0	45	39.5
7				1		45
8	1	0	0	0	55	45
9				1		52
10	1	0	1	0	65	59.5
11				1		67
12	1	1	0	0	75	72.5
13				1		80
14	1	1	1	0	85	80
15				1		90

If the Aircraft or Vehicle is longer than 85 meters, or wider than 90 meters, then decimal Aircraft/Vehicle Length/Width Code 15 **shall** be used.

2.2.3.2.7.2.12 "Track Angle/Heading" Subfield in Aircraft Operational Status Messages

The Track Angle/Heading subfield is a 1-bit field ("ME" bit 53, Message bit 85) of the ADS-B Aircraft Operational Status Message (Subtype=1, for Surface Participants) that allows correct interpretation of the data contained in the Heading/Ground Track subfield of the ADS-B Surface Position Message (§2.2.3.2.4) when the Air/Ground status is determined to be in the "On-Ground" state as defined in §2.2.3.2.1.2. The encoding of the Track Angle/Heading subfield **shall** be as specified in Table 2-75.

Table 2-75: Track Angle/Heading Encoding

Coding	Meaning
0	Track Angle
1	Heading

2.2.3.2.7.2.13 "Horizontal Reference Direction (HRD)" Subfield in Aircraft Operational Status Messages

The Horizontal Reference Direction (HRD) subfield of the ADS-B Aircraft Operational Status Messages is a 1-bit field ("ME" bit 54, message bit 86) that **shall** indicate the reference direction (true north or magnetic north) for horizontal directions such as heading, track angle. The Horizontal Reference Direction subfield **shall** be encoded as specified in Table 2-76.

Table 2-76: Horizontal Reference Direction (HRD) Encoding.

Coding	Meaning
0	True North
1	Magnetic North

2.2.3.2.7.2.14 "SIL Supplement" Subfield in Aircraft Operational Status Messages

The "SIL Supplement" (Source Integrity Level Supplement) subfield is a 1-bit ("ME" bit 55, Message bit 87) field that **shall** define whether the reported SIL probability is based on a "per hour" probability or a "per sample" probability as defined in §2.2.3.2.7.1.3.1, with the encoding specified in Table 2-46.

2.2.3.2.7.2.15 "Reserved" Subfield in Aircraft Operational Status Message

There are two "Reserved" subfields in the Aircraft Operational Status Message. The first is a 2-bit field ("ME" bits 49 and 50, Message bits 81 and 82) of the Aircraft Operational Status Message (Subtype=1, for Surface Participants). The second "Reserved" subfield is a 1-bit field ("ME" bit 56, Message bit 88) that **shall** be reserved for future applications.

2.2.3.2.7.3 TYPE Code "23" ADS-B Messages for "TEST"

TYPE "23" ADS-B Messages **shall** be used for Test Purposes. "TEST" Messages **shall** be used exclusively for the broadcast of information in support of bench and/or certification testing of 1090 MHz ADS-B systems, or for the broadcast of information of interest only to local ADS-B ground applications. "TEST" Message broadcasts will not result in an ADS-B report being generated onboard any other ADS-B equipped aircraft, nor is the specific information being included in the "TEST" Message expected to be generally codified within internationally accepted standards. "TEST" Messages containing information of interest only to local ADS-B ground applications are intended to be used in support of technical or operational evaluations, or in support of local operational requirements.

These MOPS define only one category of use for the "TEST" Messages, Subtype=0. "TEST" Messages of Subtypes 1 through 7 are reserved.

"TEST" Messages with Subtype=0 **shall** be used only for messages in support of bench and/or certification testing of 1090 MHz ADS-B systems. The format for "TEST" Messages with Subtype=0 **shall** be shown in Figure 2-12.

"TEST" Message (TYPE=23 and Subtype=0)			
MSG Bit #	33 --------------- 37	38 ------------ 40	41 ----------------- 88
"ME" Bit #	1 ----------------- 5	6 ------------- 8	9 ----------------- 56
Field Name	**TYPE=23 [5]**	**Subtype=0 [3]**	**Unformatted Test Data [48]**
	MSB LSB	MSB LSB	MSB LSB

Figure 2-12: "TEST" Message with Subtype=0 Format

2.2.3.2.7.4 Surface System Status Messages with TYPE Code=24

The Surface System Status Message is used to provide the status of certain elements of surface surveillance systems. The Surface System Status Message is intended to be used only by the surface surveillance system that generated it and should be ignored by other systems. The format of the Surface System Status Message **shall** be as specified in Figure 2.2.3.2.7.4, while further definition of each of the subfields is provided in the subsequent paragraphs.

Surface System Status Message "ME" Field Format			
Msg Bit #	33 --------------- 37	38 --------------- 40	41 ---------------- 88
"ME" Bit #	1 --------------- 5	6 ---------------- 8	9 ---------------- 56
Field Name	**TYPE = 24 [5]**	**SUBTYPE [3]**	**Surface System Status [48]**
	MSB LSB	MSB LSB	MSB LSB

Figure 2.2.3.2.7.4: "Surface System Status" ADS-B Message "ME" Field Format

2.2.3.2.7.4.1 "TYPE" Code Subfield in Surface System Status Messages

The "TYPE" Code subfield was previously specified for the Airborne Position Message in §2.2.3.2.3.1 and remains the same for the Surface System Status Message that uses TYPE Code=24.

2.2.3.2.7.4.2 "SUBTYPE" Code Subfield in Surface System Status Messages

The "SUBTYPE" Code subfield is a 3-bit ("ME" bits 6 through 8, Message bits 38 through 40) subfield that **shall** be used to indicate the source of the Surface System Status Message as specified in Table 2.2.3.2.7.4.2.

Table 2.2.3.2.7.4.2: "SUBTYPE" Subfield in Surface System Status Messages

SUBTYPE Code Subfield Encoding (decimal)	**Meaning**
0	Reserved
1	Multilateration System Status (Allocated for national use)

2 – 7	Reserved

2.2.3.2.7.4.3 "Surface System Status" Subfield in Surface System Status Messages

The Surface System Status subfield is a 48 bit ("ME" bits 9 through 56, Message bits 41 through 88) subfield that may be defined by the system equipment manufacturer.

2.2.3.2.7.5 RESERVED TYPE Code "25" ADS-B Messages

ADS-B Messages with TYPE Code=25 **shall** be Reserved for future expansion.

2.2.3.2.7.6 RESERVED TYPE Code "26" ADS-B Messages

ADS-B Messages with TYPE Code=26 **shall** be Reserved for future expansion.

2.2.3.2.7.7 RESERVED TYPE Code "27" ADS-B Messages

ADS-B Messages with TYPE Code=27 are Reserved for future expansion of these MOPS to specify Trajectory Change Message formats.

Note: *While no messages supporting Trajectory Change (TC) Reports are defined in this version of these MOPS, a possible approach to the broadcast of this information is described in Appendix O, "Accommodation of Trajectory Change Reporting.*

2.2.3.2.7.8 Extended Squitter Aircraft Status Messages with TYPE Code=28

2.2.3.2.7.8.1 Emergency / Priority Status and Mode A Code (Subtype=1)

The Extended Squitter Aircraft Status Message (TYPE Code=28) is used to provide additional information regarding aircraft status. Subtype=1 is used specifically to provide Emergency / Priority Status and the broadcast of the Mode A (4096) Code.

Specific formatting of the TYPE Code=28, Subtype=1 is specified in Figure 2-13 and in Appendix A, Figure A-8.

"1090ES Aircraft Status Message (Emergency/Priority Status) (TYPE=28, Subtype=1)"					
Msg Bit #	33 ----- 37	38 ------ 40	41 -------- 43	44 --------- 56	57 ----------- 88
"ME" Bit #	1 ------- 5	6 -------- 8	9 --------- 11	12 --------- 24	25 ----------- 56
Field Name	TYPE=28 [5]	Subtype=1 [3]	Emergency/ Priority Status [3]	Mode A Code [13]	Reserved [45]
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB

Figure 2-13: 1090ES Aircraft Status Message (Emergency/Priority Status) (TYPE=28, Subtype=1)

2.2.3.2.7.8.1.1 "Emergency/Priority Status" Subfield in Aircraft Status Messages

The "Emergency/Priority Status" subfield in the Extended Squitter Aircraft Status Message **shall** be encoded in accordance with Table 2.2.3.2.7.8.1.1.

Table 2.2.3.2.7.8.1.1: "Emergency/Priority Status" Subfield Encoding

Coding		Meaning
(Binary)	(Decimal)	
000	0	No Emergency
001	1	General Emergency
010	2	Lifeguard/medical Emergency
011	3	Minimum Fuel
100	4	No Communications
101	5	Unlawful Interference
110	6	Downed Aircraft
111	7	Reserved

a. If the pilot enters a Mode A Code of 7500, the "Emergency/Priority Status" subfield **shall** be encoded with a value of decimal 5 indicating "Unlawful Interference."

b. If the pilot enters a Mode A Code of 7600, the "Emergency/Priority Status" subfield **shall** be encoded with a value of decimal 4 indicating "No Communications."

c. If the pilot enters a Mode A Code of 7700, the "Emergency/Priority Status" subfield **shall** be encoded with a value of decimal 1 indicating "General Emergency."

d. The emergency condition initiated by the pilot entry of Mode A Code 7500, 7600 or 7700 **shall** be terminated when the pilot changes to any other Mode A Code.

Note: *The "Surveillance Status" subfield value of ONE corresponds to the emergency condition activated by Mode A Code 7500, 7600 or 7700 and the change from the value of ONE signals the termination of the emergency condition (see* §2.2.3.2.3.2).

e. If an update has not been received from an on-board data source for the "Emergency/Priority Status" within the past 5 seconds, then the "Emergency/Priority Status" subfield in the Aircraft Status Message **shall** be encoded with a value of ZERO (binary 000) indicating "No Emergency."

Note: *The encoding of the "Emergency/Priority Status" subfield values 2, 3 and 6 do not have a corresponding Mode A Code value that denotes the emergency condition. The establishment of these emergency conditions by providing a pilot interface to activate them is optional in this version of these MOPS.*

2.2.3.2.7.8.1.2 "Mode A (4096) Code" Subfield in Aircraft Status Messages

a. The Mode A (4096) Code subfield in the Aircraft Status Message **shall** be encoded as defined in RTCA DO-181D, §2.2.4.1.2 and §2.2.13.1.2.b (EUROCAE ED-73C, §3.5.2 and §3.5.6.b).

b. Starting with "ME" bit 12, the code sequence **shall** be C1, A1, C2, A2, C4, A4, ZERO, B1, D1, B2, D2, B4, D4.

Note: *The broadcast of the Mode A (4096) Code in the Aircraft Status Message with Subtype=1 is provided as a transitional feature to aid operation of ATC automation systems that use Mode A Code for Flight Plan correlation. Provisions are included in these MOPS to disable the broadcast of the Mode A Code. The requirement for the broadcast of the Mode A Code may be removed from future versions of these MOPS.*

The Mode A (4096) Code of "3000," disables the broadcast of the Mode A (4096) Code as specified in §2.2.3.3.1.4.3.1.

2.2.3.2.7.8.2 1090ES TCAS Resolution Advisory (RA) Broadcast Message (Subtype=2)

The Extended Squitter Aircraft Status Message (TYPE "28") is also used to provide additional information regarding the TCAS Resolution Advisory (RA). Subtype=2 is used specifically to provide the encoding of this information as specified in Figure 2-14. The content of the fields of the 1090ES TCAS RA Message conform to the corresponding bits of transponder Register 30_{16}, and are specified in ICAO Annex 10, Vol IV, §4.3.8.4.2.2.1.

1090ES Aircraft Status Message (TCAS RA Broadcast Message) (TYPE=28, Subtype=2)								
Msg Bit #	33 ------37	38 ----- 40	41 ----- 54	55 ----- 58	59	60	61 ----- 62	63 ---- 88
"ME" Bit #	1 ------- 5	6 ------ 8	9 ------- 22	23 ----- 26	27	28	29 ----- 30	31 ---- 56
Field Name	TYPE=28 [5]	Subtype=2 [3]	Active Resolution Advisories (ARA) [14]	RACs Record [4]	RA Terminated (RAT) [1]	Multiple Threat Encounter (MTE) [1]	Threat Type Indicator (TTI) [2]	Threat Identity Data (TID) [26]
	MSB LSB	MSB LSB	MSB LSB	MSB LSB			MSB LSB	MSB LSB

Note: *"[#]" provided in a field indicates the number of bits in that field.*

Figure 2-14: 1090ES Aircraft Status Message (TCAS RA Broadcast Message) (TYPE=28, Subtype 2)

a. The transmission of the Aircraft Status Message with Subtype=2 **shall** begin within 0.5 seconds after the transponder notification of the initiation of a TCAS Resolution Advisory.

b. The transmission of the Aircraft Status Message with Subtype=2 **shall** be terminated 24 ±1 seconds after the Resolution Advisory Termination (RAT) flag transitions from ZERO (0) to ONE (1).

c. Aircraft Status Messages with Subtype=2 **shall** have priority over Aircraft Status Messages with Subtype=1, and over all other Event-Driven Messages.

2.2.3.2.7.9 RESERVED TYPE Code "30" ADS-B Messages

ADS-B Messages with TYPE Code=30 are Reserved for future expansion.

Note: *The first version of these MOPS (RTCA DO-260) specified TYPE "30" for use in support of Operational Coordination Messages. The Operational Coordination Messages are no longer required and future editions of these MOPS may specify a different use for TYPE "30" Messages.*

2.2.3.3 ADS-B Message Transmission Rates

2.2.3.3.1 Transmission Rates for Transponder - Based Transmitters

2.2.3.3.1.1 Transmission Rates Compliant with RTCA DO-181D (EUROCAE ED-73C)

ADS-B transmitters based on Mode S transponders **shall** comply with the Message Transmit Rates specified in RTCA DO-181D (EUROCAE ED-73C), for each class of transponder defined in the latest version of FAA TSO-C112.

Note: *The requirements of RTCA DO-181D (EUROCAE ED-73C) are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.8.6.4.*

2.2.3.3.1.2 Transmission Rates Not Specified in RTCA DO-181D (EUROCAE ED-73C)

When the transmission rate of a particular message type is not specified in RTCA DO-181D (EUROCAE ED-73C), then the Mode S Transponder-Based ADS-B transmitters **shall** deliver those messages at the rates specified in the following subparagraphs for Stand Alone Transmitters. If there is conflict between the requirements of RTCA DO-181D (EUROCAE ED-73C) and this document, then the requirements of RTCA DO-181D (EUROCAE ED-73C) **shall** be adhered to.

Note: *The possible transmission time epochs should not be correlated with UTC to preclude inadvertent synchronization of transmissions from different aircraft.*

Table 2-77 summarizes the broadcast rates of the 1090ES ADS-B Messages specified in these MOPS (RTCA DO-260B).

Table 2-77: 1090 MHz Extended Squitter ADS-B Message Broadcast Rates

<table>
<tr><th rowspan="2">Transponder Register</th><th rowspan="2">Event-Driven Message Priority</th><th rowspan="2">1090ES ADS-B Message</th><th colspan="3">Broadcast Rate</th></tr>
<tr><th>On-the-Ground, not moving</th><th>On-the-Ground and moving</th><th>Airborne</th></tr>
<tr><td>BDS 0,5</td><td>N/A</td><td>Airborne Position</td><td>N/A</td><td>N/A</td><td>2 / 1 second
(0.4 – 0.6 sec)</td></tr>
<tr><td>BDS 0,6</td><td>N/A</td><td>Surface Position</td><td>LOW RATE
1 / 5 seconds
(4.8 – 5.2 sec)</td><td>HIGH RATE
2 / 1 second
(0.4 – 0.6 sec)</td><td>N/A</td></tr>
<tr><td>BDS 0,8</td><td>N/A</td><td>Aircraft Identification and Category</td><td>LOW RATE
1 / 10 seconds
(9.8 – 10.2 sec)</td><td>HIGH RATE
1 / 5 seconds
(4.8 – 5.2 sec)</td><td>HIGH RATE
1 / 5 seconds
(4.8 – 5.2 sec)</td></tr>
<tr><td>BDS 0,9</td><td>N/A</td><td>Airborne Velocity</td><td>N/A</td><td>N/A</td><td>2 / 1 second
(0.4 – 0.6 sec)</td></tr>
<tr><td rowspan="2">BDS 6,1</td><td rowspan="2">TCAS RA = 1
Emergency = 2</td><td rowspan="2">Aircraft Status
(Emergency/Priority Status, Subtype=1)
(TCAS RA Broadcast, Subtype=2)</td><td colspan="3">TCAS RA or Mode A Code Change
0.7 – 0.9 seconds</td></tr>
<tr><td colspan="3">No TCAS RA, No Mode A Change
4.8 – 5.2 seconds</td></tr>
<tr><td>BDS 6,2</td><td>N/A</td><td>Target State and Status (TSS)</td><td>N/A</td><td>N/A</td><td>1.2 – 1.3 seconds</td></tr>
<tr><td rowspan="3">BDS 6,5</td><td rowspan="3">N/A</td><td rowspan="3">Aircraft Operational Status</td><td rowspan="3">4.8 – 5.2 seconds</td><td>No change
NIC_{SUPP}/NAC/SIL
2.4 – 2.6 seconds</td><td>TSS being broadcast or not
No change TCAS/NAC/SIL
2.4 – 2.6 seconds</td></tr>
<tr><td rowspan="2">Change in
NIC_{SUPP}/NAC/SIL
0.7 – 0.9 seconds</td><td>TSS being broadcast
Change in TCAS/NAC/SIL
2.4 – 2.6 seconds</td></tr>
<tr><td>TSS not broadcast [2]
Change in TCAS/NAC/SIL
0.7 – 0.9 seconds</td></tr>
</table>

N/A = Not Applicable

Notes:

1. *Transmitters are limited to no more than 2 Event Driven messages per second. Therefore, the average of 2 Airborne Position, 2 Airborne Velocity, 0.2 Identification, and 2 Periodic Status and Event Driven messages per second, averaged over any 60 second interval, yields the required 6.2 messages per second.*
2. *Not all aircraft broadcast the Target State and Status Message (see Table 2-3).*

2.2.3.3.1.3 Maximum Transmission Rates for Transponder - Based Transmitters

The maximum ADS-B Message transmission rate **shall** not exceed 6.2 transmitted messages per second averaged over any 60 second interval, distributed as required by RTCA DO-181D, §2.2.23.1.3 (ED-73C, §3.28.3).

Note: *Transponders are limited to no more than 2 Event Driven messages per second. Therefore, the average of 2 Airborne Position, 2 Airborne Velocity, 0.2 Identification, and 2 Periodic Status and Event Driven messages per second, averaged over any 60 second interval, yields the required 6.2 messages per second.*

2.2.3.3.1.4 ADS-B Periodic Status and Event-Driven Message Broadcast Rates

2.2.3.3.1.4.1 ADS-B Target State and Status Message Broadcast Rates

a. The Target State and Status Message(s) (TYPE=29, §2.2.3.2.7.1) **shall** be initiated only when the aircraft is airborne and when vertical or horizontal target state information is available and valid as a minimum.

b. The Target State and Status Message with a Subtype value of ZERO (0) **shall**, for the nominal case, be broadcast at random intervals that are uniformly distributed over the range of 1.2 to 1.3 seconds relative to the previous Target State and Status for as long as data is available to satisfy the requirements of subparagraph "a." above.

c. The broadcast rates for Target State and Status Messages with a Subtype subfield value of other than ZERO (0) are not defined by this version of these MOPS.

Notes:

1. *Future versions of these MOPS may require unique broadcast update intervals for each Target State and Status Message Subtype (i.e., unique for each value of the Subtype subfield).*

2. *Future versions of these MOPS may require that the broadcast rate for Target State and Status Messages be temporarily increased (e.g., for 24 seconds) following any change in target state or system status information.*

2.2.3.3.1.4.2 ADS-B Aircraft Operational Status Message Broadcast Rates

The rate at which the ADS-B Aircraft Operational Status Messages (TYPE=31 and Subtype=0, §2.2.3.2.7.2) are broadcast **shall** vary depending on the following conditions:

Condition 1: Target State and Status Message (§2.2.3.2.7.1) for Target State and Status Information (i.e., TYPE=29 and Subtype=1) is not being broadcast versus being broadcast.

Condition 2: There has been a change within the past 24 seconds in the value of one or more of the following parameters included in the Operational Status Message:

a. TCAS/ACAS Operational

b. ACAS/TCAS resolution advisory active

c. NAC_p

d. SIL

a. For the two cases where:

   i. The Target State and Status Message (§2.2.3.2.7.1) with Subtype=1 is not being broadcast and Condition 2 above is not applicable (nominal condition); or

   ii. The Target State and Status Message with Subtype=1 is being broadcast regardless of the applicability of Condition 2 above;

   The Aircraft Operational Status Message **shall** be broadcast at random intervals uniformly distributed over the range of 2.4 to 2.6 seconds.

b. For the case where the Target State and Status Message (§2.2.3.2.7.1) with Subtype=1 is not being broadcast and Condition 2 above is applicable, the Aircraft Operational Status Message broadcast rate **shall** be increased for a period of 24 seconds (±1 second) such that the broadcasts occur at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds.

c. While the A/V is determined to be in the "On-Ground" condition, and Condition 2 above IS NOT applicable, then the ADS-B Aircraft Operational Status Message (TYPE=31 and Subtype=1, for surface participants, §2.2.3.2.7.2) **shall** be broadcast at random intervals that are uniformly distributed over the range of 2.4 to 2.6 seconds.

d. While the A/V is determined to be in the "On-Ground" condition, and Condition 2 above IS applicable, then the broadcast rate of the ADS-B Aircraft Operational Status Message (TYPE=31 and Subtype=1, for surface participants, §2.2.3.2.7.2) shall be increased for a period of 24 seconds (±1 second) such that the broadcasts occur at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds.

2.2.3.3.1.4.3 "Extended Squitter Aircraft Status" ADS-B Event-Driven Message Broadcast Rates

2.2.3.3.1.4.3.1 "Emergency/Priority Status Message" Broadcast Rates

The "Emergency/Priority Status Message" (TYPE=28, Subtype=1), (see §2.2.3.2.7.8) **shall** be broadcast using the Event–Driven protocol. The rate of transmission varies depending on other conditions. If the transmission of the Mode A Code is disabled, the transmission of the "Emergency/Priority Status Message" occurs only when an emergency condition is active. When the transmission of the Mode A Code is enabled, the transmission rate of the "Emergency/Priority Status Message" depends on whether the Mode A Code is changed, or if an emergency condition is active.

When the Mode A Code is set to “3000,” the 1090ES Transmitting Subsystem **shall** disable the transmission of the Mode A Code and broadcast the “Emergency/Priority Message” in accordance with §2.2.3.3.1.4.3.1.1 only when an emergency is declared. Otherwise, the Mode A Code transmission is enabled and the broadcast rates of §2.2.3.3.1.4.3.1.2 apply.

Note: *The use of Mode A Code “3000” for this purpose is in accordance with the ICAO Doc 9871 provision to disable the transmission of the Mode A Code on 1090ES. This will occur at such time that the ATC systems no longer depend on the Mode A Code to identify aircraft.*

2.2.3.3.1.4.3.1.1 “Emergency/Priority Status Message” Broadcast Rates When Transmission of Mode A Code is Disabled

When the Mode A Code transmission is disabled as per §2.2.3.3.1.4.3.1, the following transmit rates apply:

a. The “Emergency/Priority Status Message” (TYPE=28, Subtype=1) **shall** be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds relative to the previous “Emergency/Priority Status” for the duration of the emergency condition which is established by any value other than ZERO in the “Emergency/Priority Status” subfield in accordance with (§2.2.3.2.7.8.1.1).

b. In the case where there is no emergency condition established by a ZERO value in the “Emergency/Priority Status” subfield, then the “Emergency/Priority Status Message” **shall** not be broadcast.

2.2.3.3.1.4.3.1.2 “Emergency/Priority Status Message” Broadcast Rates When Transmission of Mode A Code is Enabled

When the Mode A Code transmission is enabled as per §2.2.3.3.1.4.3.1, the following transmit rates apply:

a. The “Emergency/Priority Status” (TYPE=28, Subtype=1) **shall** be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds relative to the previous “Emergency / Priority Status” under the following conditions:

   i. For a duration of 24 ±1 seconds following a Mode A Code change by the pilot except if the Mode A Code is changed to 7500, 7600 or 7700.

   Note: *The case where the Mode A Code is set to 7500, 7600 or 7700, the transmission of the emergency condition is covered by ii. below. Setting the Mode A Code to 7500, 7600 or 7700 is indicated by a Permanent Alert in the “Surveillance Status” field (value of 1) (see §2.2.3.2.3.2). A change in the Mode A Code, except to 7500, 7600 or 7700, is indicated by a Temporary Alert in the “Surveillance Status” subfield (value of 2) (see §2.2.3.2.3.2).*

ii. For the duration of an emergency condition by any non-ZERO value in the "Emergency/Priority Status" subfield in accordance with (§2.2.3.2.7.8.1.1), if the emergency code is cleared by the pilot changing the Mode A Code to other than 7500, 7600 or 7700, the broadcast of the "Emergency/Priority Status" Message **shall** be continued for 24 ±1 seconds as "i" above.

b. In the absence of conditions specified in "a" above, the "Emergency/Priority Status" Message **shall** be broadcast at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds relative to the previous "Emergency / Priority Status" Message.

2.2.3.3.1.4.3.2 "TCAS RA Broadcast Message" Broadcast Rate

A TCAS RA Broadcast (TYPE=28, Subtype=2), **shall** be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds relative to the previous "TCAS RA Broadcast Message" for the duration of the TCAS RA in accordance with §2.2.3.2.7.8.2.

2.2.3.3.1.4.4 "TYPE Code=23 (TEST)" ADS-B Event-Driven Message Broadcast Rate

The following broadcast rate requirements **shall** apply only under the condition that "TEST" Messages of the Subtype indicated are authorized to be transmitted.

The "TEST" ADS-B Event-Driven Messages with Subtype=0 **shall** be broadcast NOT MORE THAN ONCE each time the Event-Driven Test Information is updated to the transponder.

2.2.3.3.1.4.5 "TYPE Codes 24 – 27" and "TYPE Code=30" ADS-B Event-Driven Message Broadcast Rate

In general, TYPE Codes 24 - 27 ADS-B Event-Driven Messages **shall** be broadcast ONCE each time the Event-Driven TYPE Code 24 - 27 information is updated to the transponder.

2.2.3.3.1.4.6 ADS-B Message Transmission Scheduling

An ADS-B Message scheduling function **shall** be used to determine the sequence of ADS-B Messages to be broadcast and to control the overall transmission rate of Event-Driven messages.

2.2.3.3.1.4.6.1 Event-Driven Message Scheduling Function

Note: *This version of these MOPS does not define the message format for the broadcast of Trajectory Change information (§2.2.3.2.7.7). However it is anticipated that future versions of these MOPS will require the broadcast of Trajectory Change information for all Class A2 and Class A3 airborne systems and will be optional for Class A1S and A1 airborne systems. The following requirements for the Event-Driven Message Scheduling Function include provisions to accommodate the future addition of messages conveying Trajectory Change information (i.e., message TYPE=27).*

The Event-Driven Message Scheduling Function **shall** ensure that the total Event-Driven message rate does not exceed 2 transmitted messages per second. This is consistent with the required overall maximum allowed transmission rate specified in §2.2.3.3.1.3.

The Event-Driven Message Scheduling Function **shall** apply the following rules as a means of prioritizing the Event-Driven Message transmissions and limiting the transmission rates:

a. The Event-Driven Message scheduling function **shall** reorder, as necessary, pending Event-Driven Messages according to the following message priorities, listed below (and in Table 2-145) in descending order from highest to lowest priority:

   i. The broadcast of the Extended Squitter Aircraft Status Message (§2.2.3.2.7.8.1) TCAS RA Broadcast (TYPE=28, Subtype=2).

   ii. The broadcast of the Extended Squitter Aircraft Status Message (§2.2.3.2.7.8.2) Emergency/Priority Condition (TYPE=28, Subtype=1).

   iii. This priority level applies as a default to any Event-Driven Message TYPE and Subtype combination not specifically identified at a higher priority level above. Event-Driven Messages of this default priority level **shall** be delivered to the transponder on a first-in-first-out basis at equal priority.

b. The Event-Driven Message scheduling function **shall** limit the number of Event-Driven Messages provided to the transponder to two (2) messages per second.

Note: *It is possible that future versions of these MOPS, requiring a complementary change to the Mode S transponder MOPS, will allow for Event-Driven Messages to be transmitted at a rate of greater than the current limit of two (2) messages per second. Therefore, a means should be provided to allow for a future adjustment to the value used for the message rate limit in the Event-Driven Message scheduling function.*

c. If (b) results in a queue of messages awaiting delivery to the transponder, the higher priority pending messages, according to (a) above **shall** be delivered to the transponder for transmission before lower priority messages.

d. If (b) results in a queue of messages awaiting delivery to the transponder, new Event-Driven messages **shall** directly replace older messages of the same exact TYPE and Subtype (where a Subtype is defined) that are already in the pending message queue.

The updated message **shall** maintain the same position in the message queue as the pending message that is being replaced.

e. If (b) above results in a queue of messages awaiting delivery to the transponder, then pending message(s), **shall** be deleted from the message transmission queue if not delivered to the transponder for transmission, or not replaced with a newer message of the same message TYPE and Subtype, within the Message Lifetime value specified in the Table 2-78 below:

Table 2-78: Event-Driven Message Lifetime

Message TYPE	Message Subtype	Message Lifetime (seconds)
23	= 0	5.0 seconds (±0.2 sec.)
	= 1 - 7	Reserved (see Note)
24		Reserved (see Note)
25		Reserved (see Note)
26		Reserved (see Note)
27		Reserved (see Note)
28	= 1	5.0 seconds (±0.2 sec.)
	= 2	10 seconds after RAT transitions from 0 to 1
	0, > 2	Reserved (see Note)
30		Reserved (see Note)

Note: *A default message lifetime of 20 seconds will be used for queue management unless otherwise specified.*

2.2.3.3.2 Transmission Rates for Stand Alone Transmitters

a. Stand Alone Transmitters for Class A0 and Class B0 equipment are those implemented independent of a Mode S transponder. Such transmitters **shall** meet the transmission rate requirements of §2.2.3.3.1.3 and the message update rate requirements specified in the following subparagraphs.

b. Extended Squitter messages **shall** be transmitted at random intervals that are uniformly distributed over the specified time interval using a time quantization no greater than 15 milliseconds.

Note: *The possible transmission time epochs should not be correlated with UTC to preclude inadvertent synchronization of transmissions from different aircraft.*

2.2.3.3.2.1 Power-On Initialization and Start Up

2.2.3.3.2.1.1 Power-On Initialization

a. At power-up initialization, the ADS-B Transmitting Subsystem **shall** start operations in a mode in which it transmits **NO** messages.

b. Given that appropriate message data is provided to the ADS-B Transmitting Subsystem, the transmission device **shall** be capable of transmitting ADS-B Messages no later than 2.0 seconds after Power-On.

c. After a power-up initialization exceeding the momentary power interruption capability of the equipment, the total set of BITE tests that check all necessary functions of the ADS-B device **shall** be completed within 20 seconds. As a minimum, the BITE tests **shall** include RAM, ROM, I/O, Timing, CPU instruction integrity, and any associated RF hardware tests necessary to ensure proper functioning of the ADS-B device.

2.2.3.3.2.1.2 Start Up

a. The ADS-B Transmitting Subsystem **shall** initiate broadcast transmissions of the Airborne Position, Surface Position, Aircraft Identification and Category, Velocity, Target State and Status, and/or Aircraft Operational Status Messages only when it has received appropriate data to structure at least one variable data field of the respective message. As such, each message **shall** be initiated individually and independently of the other messages.

   The single exception is presented by Altitude data in the Airborne Position Message which **shall** be processed as follows:

   The ADS-B Transmitting Subsystem **shall** not initiate broadcast of the Airborne Position Message until horizontal position data has been received. That is, that altitude data alone **shall** not be sufficient to initiate broadcast of the Airborne Position Message.

b. Once ADS-B Message transmission has been initiated the transmission rate of each type of ADS-B Message **shall** be as provided in the following paragraphs.

2.2.3.3.2.2 ADS-B Airborne Position Message Broadcast Rate

Once started, ADS-B Airborne Position Messages **shall** be broadcast by the transmission device when in the Airborne state at random intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds relative to the previous Airborne Position Message, with the exceptions as specified in §2.2.3.3.2.9.

2.2.3.3.2.3 ADS-B Surface Position Message Broadcast Rate

a. Once started, ADS-B Surface Position Messages **shall** be broadcast by the transmission device when in the On-Ground state using either the “High” or “Low” rate, which has been selected as follows:

   (1). Switching from “High” rate to “Low” Rate:

      (a). The broadcast rate **shall** be changed from “High” to “Low” when the navigation source position data has not changed more than 10 meters in any 30 second interval.

         Note: *It is acceptable to compute the 10 meter distance using either rectangular or polar coordinates.*

      (b). Upon selecting the “Low” rate, the transmission device **shall** save the Position data at the time that the “Low” rate was selected.

(2). Switching from "Low" rate to "High" Rate:

The broadcast rate **shall** be changed from "Low" to "High" when the position of the transmission device has changed by 10 meters or more since the "Low" rate was selected.

Note: *It is acceptable to compute the 10 meter distance using either rectangular or polar coordinates.*

b. If the "High" rate is selected, then the Surface Position Message **shall** be transmitted at random intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds relative to the previous Surface Position Message.

c. If the "Low" rate is selected, then the Surface Position Messages **shall** be transmitted at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds relative to the previous Surface Position Message.

d. If the transmission device loses its navigation source, the "High" rate **shall** be used as the default transmission rate.

e. Exceptions to these transmission rate requirements are specified in §2.2.3.3.2.9.

2.2.3.3.2.4 ADS-B Aircraft Identification and Category Message Broadcast Rate

a. Once started, ADS-B Aircraft Identification and Category Messages **shall** be broadcast by the transmission device at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds relative to the previous Identification and Category Message, when the ADS-B Transmitting Subsystem is reporting the Airborne Position Message, or when reporting the Surface Position Message at the high rate.

b. When the Surface Position Message is being reported at the low surface rate, then the Aircraft Identification and Category Message **shall** be broadcast at random intervals that are uniformly distributed over the range of 9.8 to 10.2 seconds relative to the previous Aircraft Identification and Category Message.

c. When neither the Airborne Position Message nor the Surface Position Message is being transmitted, then the Aircraft Identification and Category Message **shall** be broadcast at the rate specified in subparagraph a.

d. Exceptions to these transmission rate requirements are specified in §2.2.3.3.2.9.

2.2.3.3.2.5 ADS-B Velocity Information Message Broadcast Rate

a. Once started, ADS-B Velocity Information Messages **shall** be broadcast by the transmission device at random intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds relative to the previous Velocity Information Message.

b. Exceptions to these transmission rate requirements are specified in §2.2.3.3.2.9.

2.2.3.3.2.6 ADS-B Periodic Status Message Broadcast Rates

2.2.3.3.2.6.1 ADS-B Target State and Status Message Broadcast Rates

a. The requirements of §2.2.3.3.1.4.1 are applicable.

b. The Target State and Status Message (TYPE=29, Subtype=0, §2.2.3.2.7.1) **shall** be broadcast at random intervals that are uniformly distributed over the range of 1.2 to 1.3 seconds relative to the previous Target State and Status Message for as long as data is available to satisfy the requirements of subparagraph "a." above.

c. Exceptions to these transmission rate requirements **shall** be as specified in §2.2.3.3.2.9.

2.2.3.3.2.6.2 ADS-B Aircraft Operational Status Message Broadcast Rates

a. The Aircraft Operational Status Message (TYPE=31 and Subtype=0 and 1) (§2.2.3.2.7.2) **shall** be broadcast at the rates as specified in §2.2.3.3.1.4.2.

b. Exceptions to these transmission rate requirements **shall** be as defined in §2.2.3.3.2.9.

2.2.3.3.2.6.3 "Extended Squitter Aircraft Status" ADS-B Event-Driven Message Broadcast Rate

a. The rate at which the "Extended Squitter Aircraft Status" (TYPE=28), ADS-B Event-Driven Message (see §2.2.3.2.7.8) **shall** be broadcast varies as defined in §2.2.3.3.1.4.3.

b. The exceptional conditions specified in §2.2.3.3.2.9 **shall** be observed.

2.2.3.3.2.7 "TYPE Code=23 (TEST)" ADS-B Event-Driven Message Broadcast Rate

The "TEST" Message with Subtype=0 ADS-B Event-Driven Messages **shall** be broadcast ***NOT MORE Than*** ONCE each time the Event-Driven Test Information is updated to the ADS-B Transmitting Subsystem. The delay conditions specified in §2.2.3.3.2.9 **shall** be observed.

2.2.3.3.2.8 "TYPE Codes 24 - 27" ADS-B Event-Driven Message Broadcast Rate

In general, TYPE Code 24 - 27 ADS-B Event-Driven Messages **shall** be broadcast ONCE each time the Event-Driven TYPE Code 24 - 27 information is updated to the ADS-B Transmitting Subsystem. The delay conditions specified in §2.2.3.3.2.9 **shall** be observed.

2.2.3.3.2.9 ADS-B Message Transmission Scheduling

a. An ADS-B Message scheduling function **shall** be used to determine the sequence of ADS-B Messages to be broadcast and to control the overall transmission rate of Event-Driven messages.

b. As an exception to the general requirement for the transmission of ADS-B Messages, the scheduled message transmission **shall** be delayed if a Mutual Suppression interface is active.

2.2.3.3.2.9.1 Position, Velocity and Identification Message Scheduling

The priority for transmission (from highest to lowest) for the message types that are not event-driven **shall** be:

a. Position Message (either Airborne Position Message, as specified in §2.2.3.2.3, or Surface Position Message, as defined in §2.2.3.2.4)

b. Airborne Velocity Message (§2.2.3.2.6)

c. Aircraft Identification and Category Message (§2.2.3.2.5)

2.2.3.3.2.9.2 Event-Driven Message Scheduling

An Event-Driven Message Scheduling function **shall**:

a. Ensure that the total Event-Driven Message rate does not exceed 2 transmitted messages per second. This is consistent with the required overall maximum allowed transmission rate specified in §2.2.3.3.2.10.

Note: *It is possible that future versions of these MOPS may allow for Event-Driven messages to be transmitted at a rate of greater than the current limit of two (2) messages per second. Therefore a means should be provided to allow for a future adjustment to the value used for the message rate limit in the Event-Driven Message scheduling function.*

b. The Event-Driven Message scheduling requirements of §2.2.3.3.1.4.6.1 **shall** be used as the means of ensuring the Event-Driven message broadcast limit of 2 messages per second is not exceeded.

2.2.3.3.2.10 Maximum ADS-B Message Transmission Rates

The maximum ADS-B Message transmission rate of non-transponder ADS-B Transmitter implementations **shall not** exceed 6.2 transmitted messages per second, averaged over any 60 second interval.

Note: *It is possible that future versions of these MOPS may allow for ADS-B Messages to be transmitted at a rate of greater than the current limit of 6.2 messages per second. Therefore a means should be provided to allow for a future adjustment to the value used for the message rate limit in the message scheduling function.*

2.2.3.3.2.11 ADS-B Message Timeout

Notes:

1. *These messages are cleared to prevent the reporting of outdated position and velocity information.*

2. *During a register timeout event, the "ME" field of the ADS-B Broadcast Message may contain ALL ZEROs, except for those fields that may be updated due to the receipt of new data.*

a. The ADS-B Transmitting Subsystem **shall** clear all but the altitude and surveillance status subfields of the Airborne Position Message, if no new position data is received within two (2) seconds of the previous input data update.

Note: *During a timeout event the Format TYPE Code is set to ZERO (see §2.2.3.2.3.1.3.1).*

b. The ADS-B Transmitting Subsystem **shall** clear all 56-bits of the Surface Position Message if no new position data is received within two (2) seconds of the previous input data update.

Notes:

1. *During a timeout event the Format TYPE Code is set to ZERO (see §2.2.3.2.4.1.3.1).*

2. *When position is available, the ADS-B Transmitting Subsystem manages the movement and the ground track subfields such that the subfields and applicable status bits are set to ZERO (0) if no new data is received for the subfield within 2.6 seconds of the last data update of the subfield.*

3. *When position data is not received, all bits of the Surface Position Message are set to ZERO to avoid confusion with altitude data in the Airborne Position Message sent with TYPE Code ZERO (0).*

c. The ADS-B Transmitting Subsystem **shall** clear all 56-bits of the Airborne Velocity Message if no data is received within 2.6 seconds of the previous input data update.

Note: *The Intent Change information is not sufficient to consider that new data has been received (§2.2.3.2.6.1.3).*

d. The ADS-B Transmitting Subsystem **shall not** clear the Aircraft Identification Message (see §2.2.3.2.5).

Note: *The Aircraft Identification Message, is not cleared since it contains data that rarely changes in flight and is not frequently updated.*

e. The ADS-B Transmitting Subsystem **shall** clear each of the Selected Altitude, Selected Heading, or Barometric Pressure Setting subfields of the Target State and Status Message (see §2.2.3.2.7.1) if no new data is received within 2.0 seconds of the previous input data update for the respective subfield. Each of the subfields **shall** be cleared independently of the other subfields. That is, each of the three specified subfields **shall** be processed mutually exclusively of the other two specified subfields. The remaining subfields of the Target State and Status Message **shall not** be cleared, as they contain other integrity, mode, or status information.

f. The ADS-B Transmitting Subsystem **shall not** clear the Operational Status Messages (see §2.2.3.2.7.2) since the subfields of the Message contain various integrity, mode, or status information..

g. The ADS-B Transmitting Subsystem **shall not** clear the Event-Driven Messages (see §2.2.3.2.7.8).

Note: *The Event-Driven Messages do not need to be cleared since contents of such messages are only broadcast once each time that new data is received.*

2.2.3.3.2.12 ADS-B Message Termination

a. The ADS-B Transmitting Subsystem **shall** terminate broadcast transmissions of the Airborne Position Message when position (latitude/longitude) and altitude data are not available for a period of 60 seconds.

Note: *For the Airborne Position Message, altitude data alone is sufficient to maintain broadcast of the Message once the Message has been initiated. When only altitude data is available, the Airborne Position Message continues to be transmitted even after 60 seconds. However, if the altitude data is not available for 60 seconds, then the Airborne Position Message transmission is terminated and the conditions for start-up defined in §2.2.3.3.2.1.2 are necessary to resume the transmission of Airborne Position Message.*

b. The ADS-B Transmitting Subsystem **shall** terminate the transmission of Surface Position Messages if position data that is necessary to update the Message is not available for a period of 60 seconds. Transmission termination of Surface Position Messages does not apply to Non-Transponder Devices on aircraft that are on the surface, or on surface vehicles.

Note: *For the Surface Position Message, the receipt of new Movement, or Ground Track data is not sufficient to maintain broadcast of the message once the message has been initiated.*

c. The ADS-B Transmitting Subsystem **shall not** terminate broadcast transmissions of Aircraft Identification and Category Message even if input data necessary to update the Message is not available.

d. The ADS-B Transmitting Subsystem **shall** terminate broadcast transmissions of the Airborne Velocity Message if input data necessary to update the subfields of the Airborne Velocity Message, other than the Intent Change Flag, is not available for a period of 2.6 seconds.

Notes:

1. The receipt of new data necessary to update any single subfield, other than the Intent Change Flag, is sufficient to maintain broadcast of the Airborne Velocity Message.

2. Previous versions of these MOPS required the Airborne Velocity Message to be transmitted for an additional 60 seconds with ALL ZEROs including the TYPE Code field. In the event of a loss of GPS data the Airborne Position Message would have barometric altitude in it, the Airborne Velocity Message would not. However, a receiver could not determine the difference between these cases, therefore the transmitted altitude was not usable.

e. The ADS-B Transmitting Subsystem **shall** continue to broadcast the Target State and Status Message for as long as Airborne Position Messages are being broadcast.

Note: *Target State and Status Messages do not need to be terminated until the Airborne and Surface Position Messages are terminated since the Target State and Status Messages contain various integrity, mode, or status information that is applicable to the Airborne Position Messages.*

f. The ADS-B Transmitting Subsystem **shall** continue to broadcast the Operational Status Messages for as long as Airborne Position Messages or Surface Position Messages are being broadcast.

Note: *Operational Status Messages do not need to be terminated until the Airborne Position Messages and the Surface Position Messages are terminated since the Operational Status Messages contain various integrity, mode, or status information that is applicable to the Airborne Position Messages or the Surface Position Messages.*

g. Class B2 Non-Transponder-Based Transmitting Subsystems on Ground Vehicles **shall** provide an interface capable of putting the unit into a standby condition in which the unit suspends all message transmissions.

Notes:

1. *This interface is intended to be used by a mapping function that will automatically trigger the interface if the Transmitting Subsystem is outside a user adaptable two-dimensional geographic area.*

2. *If required because of spectrum considerations, the two-dimensional geographic area will be defined as the movement area (i.e., runways and taxiways) plus a reasonable buffer area (i.e., 50 foot buffer). Implementations of this feature should be designed such that a particular ground authority can specify a region that conserves spectrum without introducing risk of accidental termination within the movement area. Consideration should be given to precision and accuracy of the geographic region definition.*

3. *As a vendor option, this mapping function may be implemented integral to the Class B2 equipment. In this case, the interface is internal to the unit.*

2.2.3.4 ADS-B Transmitted Message Error Protection

Error protection **shall** be provided by the ADS-B Transmitting Subsystem encoding all messages in accordance with the requirements provided in RTCA DO-181D, §2.2.18.2.1 (EUROCAE ED-73C, §3.22.2.1) and illustrated in Figure 2-11 of RTCA DO-181D (EUROCAE ED-73C, Figure 3-9).

Note: *The requirements of RTCA DO-181D, §2.2.18.2.1 and Figure 2-11 (EUROCAE ED-73C, §3.22.2.1 and Figure 3-9) are consistent with the requirements of ICAO Annex 10, Volume IV, fourth edition, July 2007, §3.1.2.3.3.*

2.2.4 ADS-B Receiver Characteristics

2.2.4.1 Minimum Triggering Level (MTL) Definition

a. The sensitivity of the ADS-B Receiver is sufficient to reliably detect and decode ADS-B Messages provided the received power is at or above a certain level. The receiver sensitivity requirements are stated in terms of the Minimum Triggering Level (MTL) specified in the following paragraphs.

b. Given a valid ADS-B Message signal that complies with the frequency, pulse spacing and pulse width requirements, and in the absence of interference or overloads, the MTL of an ADS-B receiver is defined as the received power level that results in a successful message reception ratio of 90%.

2.2.4.2 Receivers Shared with a TCAS Unit

a. ADS-B Receiving Subsystems implemented as part of a TCAS unit **shall** comply with all receiver requirements specified in the TCAS MOPS, RTCA DO-185B, §2.2.4.4 (EUROCAE ED-143, §2.2.4.4).

b. ADS-B Receiving Subsystems operating with TCAS units that are more sensitive than the MTL requirements specified in RTCA DO-185B (EUROCAE ED-143), **shall** implement the capabilities specified in §2.2.4.2.1 through §2.2.4.4.

Note: *The TCAS MOPS, RTCA DO-185B (EUROCAE ED-143), uses the term "Extended Squitter" to refer to messages having the same formats and transmission requirements as those messages referred to as ADS-B Messages in this document. These terms should be accepted as being equivalent when referring to the TCAS system.*

2.2.4.2.1 Dual Minimum Triggering Levels

Note: *A TCAS receiver that is also used as an ADS-B receiver will have a minimum triggering level (MTL) that is more sensitive than a standard TCAS receiver. Such a receiver must implement dual MTLs so that it is capable of setting an indication for each squitter reception as to whether the reply would have been detected by a TCAS operating with a standard MTL. Squitter receptions received at the standard MTL will be passed to the TCAS surveillance function for further processing. Squitter receptions that do not meet this condition will be not passed to the TCAS surveillance function.*

2.2.4.2.1.1 TCAS Compatibility

No more than 10% of all ADS-B Messages received at an input signal level of -78 dBm or less **shall** be delivered to the TCAS functions specified in RTCA DO-185B (EUROCAE ED-143).

Note: *Use of the standard TCAS MTL (-74 +2dB as specified in RTCA DO-185B §2.2.4.4.1.1.a (EUROCAE ED-143, §2.2.4.4.1.1.a)) for the TCAS surveillance functions preserves the current operation of TCAS surveillance when operating with a receiver with an improved MTL, such as those inferred in §2.2.4.3.1.*

2.2.4.2.1.2 ADS-B Compatibility

All ADS-B Messages **shall** be processed in accordance with §2.2.4.3.1.1.

2.2.4.2.2 Re-Triggerable Reply Processor

The TCAS Mode S reply processing function **shall** use a Mode S reply processor that will re-trigger if it detects a Mode S preamble that is at least 3 dB stronger than the reply that is currently being processed in order to ensure that the stronger signal is processed.

Note: *Care must be taken to ensure that low-level squitters (i.e., those below the nominal TCAS MTL) do not interfere with the processing of acquisition squitters for TCAS. This may happen if the low-level squitter is allowed to capture the reply processor. This may be prevented by using a separate reply processor for each function, or by requiring the reply processor to be re-triggered by a higher level squitter message.*

2.2.4.3 Receivers Not Shared With TCAS

2.2.4.3.1 In-Band Acceptance and Re-Triggerable Capability

2.2.4.3.1.1 In-Band Acceptance

The requirements provided in the following subparagraphs are specified at the Antenna end of an Antenna to Receiver transmission line having loss equal to the maximum for which the receiving installation is designed.

a. The MTL of an ADS-B receiver processing signals over the frequency range of 1089 to 1091 MHz **shall** comply with the MTL limits provided in Table 2-79 for the applicable receiver Equipment Class.

Table 2-79: ADS-B Class "A" Equipment Receiver Sensitivity

EQUIPMENT CLASS	A0	A1S/A1	A2	A3
MTL	**-72** dBm	**-79** dBm	**-79** dBm	**-84** dBm

Note: *The MTL limits of Table 2-79 must be complied with over the entire environmental operating range specified by the manufacturer of the receiver (e.g., receiver performance variations over temperature and other conditions must be taken into account).*

b. In the absence of interference or overloads, each ADS-B receiver **shall** properly detect and decode at least 99% of all ADS-B Messages received at an input signal level between the levels of MTL + 3 dB and -21 dBm.

c. In the absence of interference or overloads, each ADS-B receiver of equipment Class A3 **shall** properly detect and decode at least 15% of all ADS-B Messages received at an input signal level of -87 dBm.

Notes:

1. *This requirement need only be tested under ambient conditions.*

2. *The intent of this requirement is to emphasize the desirability of taking advantage of signals received below the required MTL.*

2.2.4.3.1.2 Re-Triggerable Capability

ADS-B receivers having Equipment Class A1S, A1, A2 or A3 capability **shall** re-trigger if such receivers detect an ADS-B Message having a preamble that is at least 3 dB stronger than that of the message that is currently being processed.

Note: *This requirement is required in order to ensure that the ADS-B processor will properly detect and process the stronger signal.*

2.2.4.3.2 Out-of-Band Rejection

For out-of-band signals the ADS-B Message signal level required to provide 90 percent ratio of decoded and accepted messages to the number of actual messages transmitted **shall** increase relative to the equipment MTL at 1090 MHz as provided in Table 2-80.

Table 2-80: ADS-B Receiver Out -of- Band Rejection

Message Frequency Difference (MHz from 1090 MHz)	Triggering Level (dB above MTL)
± 5.5	Greater Than or Equal to **3**
± 10	Greater Than or Equal to **20**
± 15	Greater Than or Equal to **40**
± 25	Greater Than or Equal to **60**

2.2.4.3.3 Dynamic Minimum Trigger Level (DMTL)

ADS-B single receiver systems **shall** implement Dynamic Minimum Trigger Level (DMTL) control as a mean of rejecting low level multipath signals and interference.

If the enhanced reception techniques (§2.2.4.4) are used, then the DMTL characteristics shall be compatible with the requirements in §2.2.4.4. Otherwise, the DMTL characteristics shall be compatible with the requirements in §2.2.4.3.4.1 through §2.2.4.3.4.3.

2.2.4.3.4 1090 MHz ADS-B Message Reception Techniques

2.2.4.3.4.1 ADS-B Message Reception

a. When listening for ADS-B Messages and upon receipt of a single pulse of greater than 300 nanoseconds duration and having amplitude **A**, where **A** exceeds MTL +8 dB, the receiver threshold **shall** increase to **A** -6 dB ±1 dB for a period of not less than five microseconds following the leading edge of the first pulse and **shall** be recovered in not more than eight microseconds, unless a valid or qualifying preamble is received (§2.2.3.1.1), in which case the threshold **shall** be held at **A** -6 dB +1 dB for a period of not less than 115 microseconds and **shall** be recovered in not more than 120 microseconds.

   The receiver threshold **shall** at no time exceed **A** -5 dB except for possible overshoot during the first microsecond following the leading edge of the first pulse.

b. If **A** is less than MTL +8 dB, there is no requirement to raise the threshold.

Notes:

1. *The length of an ADS-B Message cannot be determined with certainty by the DMTL system. Therefore, the ADS-B Message DMTL desensitizes for the duration of the ADS-B Message.*

2. *These requirements are consistent with the requirements of RTCA DO-185, §2.2.2.3.2. Note that there is no direct correlation to these requirements provided in RTCA DO-185A. In fact, RTCA DO-185A has deleted the DMTL requirements previously provided and now relies completely on Whisper Shout level control techniques to provide multipath rejection (see §2.2.4.5.1 or RTCA DO-185A).* ***➔ XXXXXXXX TBD XXXXXXXX What do we do about this note ?? ➔***

2.2.4.3.4.2 Narrow Pulse Discrimination

The DMTL control **shall** not be responsive to pulses that have a width of less than 0.3 microseconds.

Note: *These requirements are consistent with the requirements of RTCA DO-185B, §2.2.4.5.1.2.1 (EUROCAE ED-143, §2.2.4.5.1.2.1).*

2.2.4.3.4.3 TACAN and DME Discrimination

The DMTL control **shall** not be responsive to TACAN or DME pulses.

Note: *These requirements are consistent with the requirements of RTCA DO-185B, §2.2.4.5.1.2.2 (EUROCAE ED-143, §2.2.4.5.1.2.2).*

2.2.4.3.4.4 Pulse Characteristics of Received ADS-B Messages

All pulse characteristics of the ADS-B Messages were previously specified in §2.2.2.2.1 and §2.2.3.1 and associated subparagraphs of this document.

2.2.4.3.4.5 Message Formats

The 1090 MHz receiver **shall** correctly decode all valid ADS-B Messages received in accordance with the requirements specified in §2.2.4.3.1.1 through §2.2.4.3.4.4. A valid Extended Squitter message follows the format specified in RTCA DO-181D (EUROCAE ED-73C) with the "PI" field specified with "II"=0 and "SI"=0.

General formats of the Extended Squitter (i.e., ADS-B) Messages was provided is §2.2.3.1 through §2.2.3.2.1.7 of this document.

2.2.4.3.4.6 Description of 1090 MHz ADS-B Message Received Signals

Formats of ADS-B transmitted messages were previously specified in §2.2.3.2.3 through §2.2.3.2.7 of this document.

2.2.4.3.4.7 ADS-B Signal Reception

2.2.4.3.4.7.1 Criteria for ADS-B Message Transmission Pulse Detection

a. ADS-B Message transmission pulse decoding **shall** be based on pulse leading edges.

Note: *The occurrence of a leading edge may be determined directly from a positive slope or inferred from pulse widths and trailing edge positions. An actual leading edge is defined as an event for which: the signal rises at a rate exceeding 48 dB per microsecond to a level above the receiver threshold **AND** 0.125 microseconds later the rate of rise is less than 48 dB per microsecond. An inferred leading edge is defined as an event in which a leading edge is assumed to exist in order to account for a pulse whose width implies the existence of overlapping pulses.*

a. All performance requirements **shall** be met for pulses having the following characteristics:

(1).	Pulse Amplitude Variation:	up to +2 dB, relative to the amplitude of the first preamble pulse
(2).	Pulse rise time:	0.1 microsecond or less
(3).	Pulse decay time:	0.2 microseconds or less

2.2.4.3.4.7.2 Criteria for Preamble Acceptance

The first qualifying criterion for reception of an ADS-B 1090 MHz message signal **shall** be the reception of the Preamble (§2.2.3.1.1). A preamble **shall** be accepted if each of the four pulse positions of the preamble waveform contains a pulse that is above the receiver threshold for at least 75 percent of its nominal duration, ***AND*** the last three pulses are within ±0.125 microseconds of their nominal position relative to the first pulse, ***AND*** at least two of the four preamble pulses have actual leading edges (as specified in §2.2.4.3.4.7.1.a) that occur within ±0.125 microseconds of their nominal edge positions. All inferred leading edges **shall** occur within ±0.125 microseconds of the expected nominal position.

Note: *Appendix "I" provides description of an improved implementation.*

2.2.4.3.4.7.3 Criteria for Data Block Acceptance in ADS-B Message Signals

ADS-B Messages always contain 112 data bits. Each bit of the 1090 MHz ADS-B Message Data Block **shall** be decoded by comparing the received signal with a 0.5 microsecond delayed replica of itself to determine the difference between the signal amplitudes at the centers of the two possible pulse positions for that bit.

The ADS-B transmission **shall** be accepted as a valid ADS-B Message if:

a. The first five bits of the data block contain either the code 1 0001 or 1 0010 (i.e., either DF=17 or DF=18);

b. ***AND*** no error is detected, ***OR*** error correction performed in accordance with §2.2.4.4.2.2.d and Appendix A, Section 3 of RTCA DO-185B (EUROCAE ED-143,

§2.2.4.4.2.2.d) can be successfully applied, ***AND*** no more than seven consecutive data bits fail the following confidence test:

Sample the received signal at least eight times during the one microsecond bit interval to determine if the amplitude of the received signal is above or below the dynamic minimum triggering level of the receiver. The data bit **shall** be declared a high-confidence bit if, between the first and second of the two possible pulse positions for that bit, the difference in the number of samples for which the signal is above DMTL is at least three ***AND*** the sign of this difference agrees with the decoded value of the bit.

Notes:

1. *Alternative equivalent methods are acceptable, provided that the manufacturer provides evidence that performance is not degraded.*

2. *Acceptance of ADS-B transmissions with the first five bits identified as 1 0011 (i.e., DF=19) is optional.*

2.2.4.3.5 ADS-B Receiver Duty Factor

Available ADS-B receiver duty factor (i.e., the percentage of time that the ADS-B Message Reception function is able to receive and process ADS-B Messages at the required ADS-B MTL), when the receiver is shared with another receiving function using the 960-1215 MHz band, is an important consideration in meeting the intended ranges of operation for ADS-B equipment. The available ADS-B receiver duty factor **shall** be 90% or greater, averaged over a 10 second period. As an exception, if the available ADS-B receiver duty factor is less than 90 percent, techniques for achieving equivalent performance may be proposed and substantiated by analysis.

2.2.4.4 Enhanced Squitter Reception Techniques

2.2.4.4.1 Need for Enhanced Techniques

The 1090 MHz ADS-B Message Reception Techniques specified in §2.2.4.3.4 provide a high probability of correct reception when the desired squitter is overlapped with one ATCRBS interfering reply of equal or greater power. In some high interference environments (e.g., Los Angeles or Frankfurt, Germany), there is a relatively high probability that the desired squitter signal will be overlapped with two or more ATCRBS replies. In these environments, the air-to-air range may be reduced because of the effects of this interference.

2.2.4.4.2 Enhanced Squitter Reception Technique Overview

Enhanced squitter reception techniques have been developed (see Appendix I) that provide the ability to receive squitters with multiple overlapping Mode A/C FRUIT. Such enhanced reception techniques are composed of the following elements:

a. Improved preamble detection to reduce the probability of a false alarm caused by detection of an apparent Mode S preamble synthesized by overlapped Mode A/C FRUIT replies.

b. Improved code and confidence bit declaration typically based on the use of amplitude to aid in the interpretation of the squitter data block.

c. More capable error correction techniques that are optimized to the characteristics of the code and confidence process.

Class A1S, A1, A2 and A3 equipment **shall** demonstrate compliance with test procedures specified in §2.4.4.4 and its subparagraphs.

Note: *The full set of enhanced techniques are applicable to Class A2 and A3 receiving equipment. Class A1S and A1 receiving equipment requires only a subset of the enhanced reception capabilities, and this is reflected in the test procedures of §2.4.4.4 and its subparagraphs.*

2.2.4.4.3 Error Correction

2.2.4.4.3.1 Error Correction Requirements

The ADS-B Receiving Subsystem **shall** either

a. use "conservative" and "brute force" error correction techniques as defined in §I.4.3, or

b. use alternative error correction techniques that are demonstrated to provide no more than 1 x (10^{-6}) report error rate.

2.2.4.4.3.2 Error Correction Restrictions

The enhanced reception techniques are intended to operate in very high Mode A/C FRUIT environments. For this reason, the sliding window error correction technique **shall not** be used in conjunction with the enhanced techniques since it produces an unacceptably high undetected error rate in these high FRUIT environments.

Note: *See Appendix I, §I.3.3 and §I.4.3 for more details on error correcting techniques.*

2.2.4.5 ADS-B Received Message Error Protection

a. Error protection **shall** be provided by the ADS-B Receiving Subsystems decoding all messages that have been encoded in accordance with the requirements provided in RTCA DO-181D, §2.2.18.2.1.c and illustrated in Figure 2-11 of RTCA DO-181D (EUROCAE ED-73C, §3.22.2.1.c and Figure 3-10).

b. Error correction techniques for equipment class A0 **shall** be applied by the ADS-B Receiving Subsystems in accordance with RTCA DO-185B, Appendix A, §A.3 (EUROCAE ED-143, §A.3).

c. Error correction techniques for equipment Classes A1S, A1, A2 and A3 are specified in §2.2.4.4.2.

2.2.5 ADS-B Transmission Device Message Processor Characteristics

The primary functions of the ADS-B Transmission Device Message Processor are described in the following subparagraphs.

2.2.5.1 ADS-B Transmission Device Data Processing and Message Formatting

2.2.5.1.1 Participant Address

2.2.5.1.1.1 ICAO 24-Bit Discrete Address

The ADS-B Transmitting Subsystem **shall** accept the ICAO 24-bit Discrete Address via an appropriate data input interface. For Transponder-Based systems, the ADS-B Transmitting Subsystem **shall** format such data into the "AA" field (§2.2.3.2.1.5), Message bits 9 through 32, of ALL ADS-B Message Transmissions as identified in Figure 2-2. Non-Transponder-Based systems **shall** format such data when selecting the "24-Bit ICAO Address" from the Address Qualifier input specified in §2.2.5.1.1.3.

The ADS-B Transmitting Subsystem shall read in and store the ICAO 24-bit Discrete Address during power-up initialization. For Transponder-Based Systems, the address **shall not** change from the value stored at power-up, as required by RTCA DO-181D. For Non-Transponder-Based Systems, if a means to change the ICAO 24-bit Address is provided and permitted by the appropriate regulatory authority, the change **shall** only be accepted while in standby mode as per section §4.4.6.

2.2.5.1.1.2 Anonymous Address

For Non-Transponder-Based systems, the use of an Anonymous Address may be allowed under certain conditions. When an Anonymous Address is used the ADS-B Transmitting Subsystems **shall** accept the Anonymous Address via an appropriate data input interface. The Anonymous Address shall only be accepted while in standby mode as per section 4.4.6. The ADS-B Transmitting Subsystem **shall** format such data into the "AA" field (§2.2.3.2.1.5), Message bits 9 through 32, of ALL ADS-B Message Transmissions when selecting "Anonymous Address" from the Address Qualifier input specified in §2.2.5.1.1.3.

2.2.5.1.1.3 Address Qualifier for Non-Transponder Devices

For Non-Transponder-Based systems, the ADS-B Transmitting Subsystems **shall** accept the Address Qualifier selection via an appropriate data input interface. The input **shall** select between the "24-Bit ICAO Address" and the "Anonymous Address" to be transmitted in the "AA" field (§2.2.3.2.1.5), Message bits 9 through 32, of ALL ADS-B Message Transmissions.

2.2.5.1.2 ADS-B Emitter Category Data

The ADS-B Transmitting Subsystem **shall** accept the ADS-B Emitter Category (see §2.2.3.2.5.2) via an appropriate data input interface and use such data to establish the "ADS-B Emitter Category" Subfield in Aircraft Identification and Category Messages (see §2.2.3.2.5) as specified in §2.2.3.2.5.2.

If the ADS-B Emitter Category is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROS into the "ADS-B Emitter Category" Subfield in the Aircraft Identification and Category Message.

2.2.5.1.3 Air/Ground Status Data

The ADS-B Transmitting Subsystem **shall** accept Air/Ground status information via an appropriate data input interface and use such data to establish the "CA" Capability Field as specified in §2.2.3.2.1.2.

If the ADS-B Transmitting Subsystem does not accept Air/Ground status information via automatic means, the "CA" Capability field **shall** be set to 6 or 7 as specified in Table 2-8 in §2.2.3.2.1.2.

2.2.5.1.4 Surveillance Status Data

The ADS-B Transmitting Subsystem **shall** accept Surveillance status information via an appropriate data input interface and use such data to establish the "Surveillance Status" subfield in the ADS-B Airborne Position Message (see §2.2.3.2.3) as specified in §2.2.3.2.3.2.

Note: *The Surveillance Status information interface is an internal interface in transponder implementations.*

2.2.5.1.5 Altitude Data

a. **Pressure Altitude --** The ADS-B Transmitting Subsystem **shall** accept Barometric Altitude (see §2.2.3.2.3.4.1) information via an appropriate variable data input interface and use such data to establish the "Altitude" subfield in the ADS-B Airborne Position Message (see §2.2.3.2.3) as provided in §2.2.3.2.3.4 through §2.2.3.2.3.4.3 with the following additional constraints:

   (1). When operated in conjunction with a pressure-altitude encoder (digitizer) or an air data system, the ADS-B Transmitting Subsystem **shall** have the capability for pressure-altitude transmission up to its designed maximum altitude.

   (2). If pressure-altitude Data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the Altitude subfield specified in §2.2.3.2.3.4.

b. **GNSS Height Above the Ellipsoid (HAE)** -- The ADS-B Transmitting Subsystem **shall** accept GNSS Height Above the Ellipsoid (HAE) (see §2.2.3.2.3.4.2) information via an appropriate variable data input interface and use such data to establish subfields in ADS-B transmitted messages as follows:

(1). The "Altitude" subfield in the ADS-B Airborne Position Message (see §2.2.3.2.3) as provided in §2.2.3.2.3.4.2 through §2.2.3.2.3.4.3,

(2). The "Difference From Barometric Altitude Sign Bit" subfield (see §2.2.3.2.6.1.14) in the Airborne Velocity Subtype "1 & 2" (see §2.2.3.2.6.1 and §2.2.3.2.6.2) as specified in §2.2.3.2.6.1.14 and §2.2.3.2.6.2.14, respectively,

(3). The "Difference From Barometric Altitude Sign Bit" subfield (see §2.2.3.2.6.1.14) in the Airborne Velocity Subtype "3 & 4" (see §2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.15 and §2.2.3.2.6.4.15, respectively,

(4). The "Difference From Barometric Altitude" subfield (see §2.2.3.2.6.1.15) in the Airborne Velocity Subtype "1 & 2" (see §2.2.3.2.6.1 and §2.2.3.2.6.2) as specified in §2.2.3.2.6.1.15 and §2.2.3.2.6.2.15, respectively, and

(5). The "Difference From Barometric Altitude" subfield (see §2.2.3.2.6.1.15) in the Airborne Velocity Subtype "3 & 4" (see §2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.15 and §2.2.3.2.6.4.15, respectively,

If appropriate "GNSS Height Above the Ellipsoid (HAE)" data is not available to the ADS-B Transmitting Subsystem, then the device **shall** set all subfields identified above in subparagraphs (1). through (5). to ZERO.

c. **GNSS Altitude (MSL)** -- If GNSS Height Above the Ellipsoid (HAE) data is not available to the ADS-B Transmitting Subsystem, then the device may accept GNSS Altitude (MSL) data and use such data to establish the subfields identified above in subparagraphs b.(1). through b.(5).

d. **NO GNSS Height/Altitude Data** -- If neither GNSS Height Above the Ellipsoid (HAE) nor GNSS Altitude (MSL) data are available to the ADS-B Transmitting Subsystem, then the device **shall** set all subfields identified above in subparagraphs b.(1). through b.(5). to ZERO.

2.2.5.1.6 Time Data and Time Mark Pulse

The ADS-B Transmitting Subsystem **shall** accept GPS/GNSS Time Mark information as provided in the following subparagraphs.

2.2.5.1.6.1 Case, where TIME ("T") = 0

a. If the ADS-B Transmitting Subsystem is not capable of setting the "TIME" ("T") subfield (see §2.2.3.2.3.5) in the Airborne Position Message (see §2.2.3.2.3) or in the Surface Position Message (see §2.2.3.2.4), then the ADS-B Transmitting Subsystem **shall** set the "TIME" subfield to ZERO.

b. Whenever the ADS-B Transmitting Subsystem is setting the "TIME" ("T") subfield to ZERO as provided in subparagraph a., then the ADS-B Transmitting Subsystem **shall** not be required to accept and process GPS/GNSS Time Mark information.

2.2.5.1.6.2 Case, where TIME ("T") = 1

a. If the ADS-B Transmitting Subsystem is capable of setting the TIME ("T") subfield (see §2.2.3.2.3.5) to ONE in the Airborne Position Message (see §2.2.3.2.3) or in the Surface Position Message (see §2.2.3.2.4), then the ADS-B Transmitting Subsystem **shall** accept and process a GPS/GNSS Time Mark pulse or an equivalent time synchronization indication from the source of navigation data.

b. The leading edge of the GPS/GNSS Time Mark pulse, or equivalent, **shall** indicate the exact moment (epoch of the UTC time scale) ±5 milliseconds that represents the time of applicability of Position, Velocity, and Time (PVT) information that is received from the navigation source.

   Note: *A possible implementation of the GPS/GNSS Time Mark pulse is illustrated in Figure 2-15. The PVT data is expected to be provided by the navigation data source no later than 200 milliseconds after the leading edge of the GPS/GNSS Time Mark pulse, or equivalent.*

c. When the ADS-B Transmitting Subsystem sets the TIME ("T") subfield to ONE in the Airborne Position Message (see §2.2.3.2.3), then the ADS-B Transmitting Subsystem **shall** use the GPS/GNSS Time Mark pulse to accomplish the following:

   (1). Synchronize the loading of the Airborne Position Message such that the register is properly loaded 100 milliseconds ±50 milliseconds prior to the time of applicability of the data being loaded into the register.

   (2). Establish the "Time" subfield in ADS-B Airborne Position Messages (see §2.2.3.2.3) as specified in §2.2.3.2.3.5,

   (3). Establish the "CPR Format" subfield in ADS-B Airborne Position Messages (see §2.2.3.2.3) as specified in §2.2.3.2.3.6, (4). Extrapolate Airborne Latitude Position in ADS-B Airborne Position Messages (see §2.2.3.2.3) as specified in §2.2.3.2.3.7.2.

(5). Extrapolate Airborne Longitude Position in ADS-B Airborne Position Messages (see §2.2.3.2.3) as specified in §2.2.3.2.3.8.2,

d. When the ADS-B Transmitting Subsystem sets the TIME (“T”) subfield to ONE in the Surface Position Message (see §2.2.3.2.4), then the ADS-B Transmitting Subsystem **shall** use the GPS/GNSS Time Mark pulse to accomplish the following:

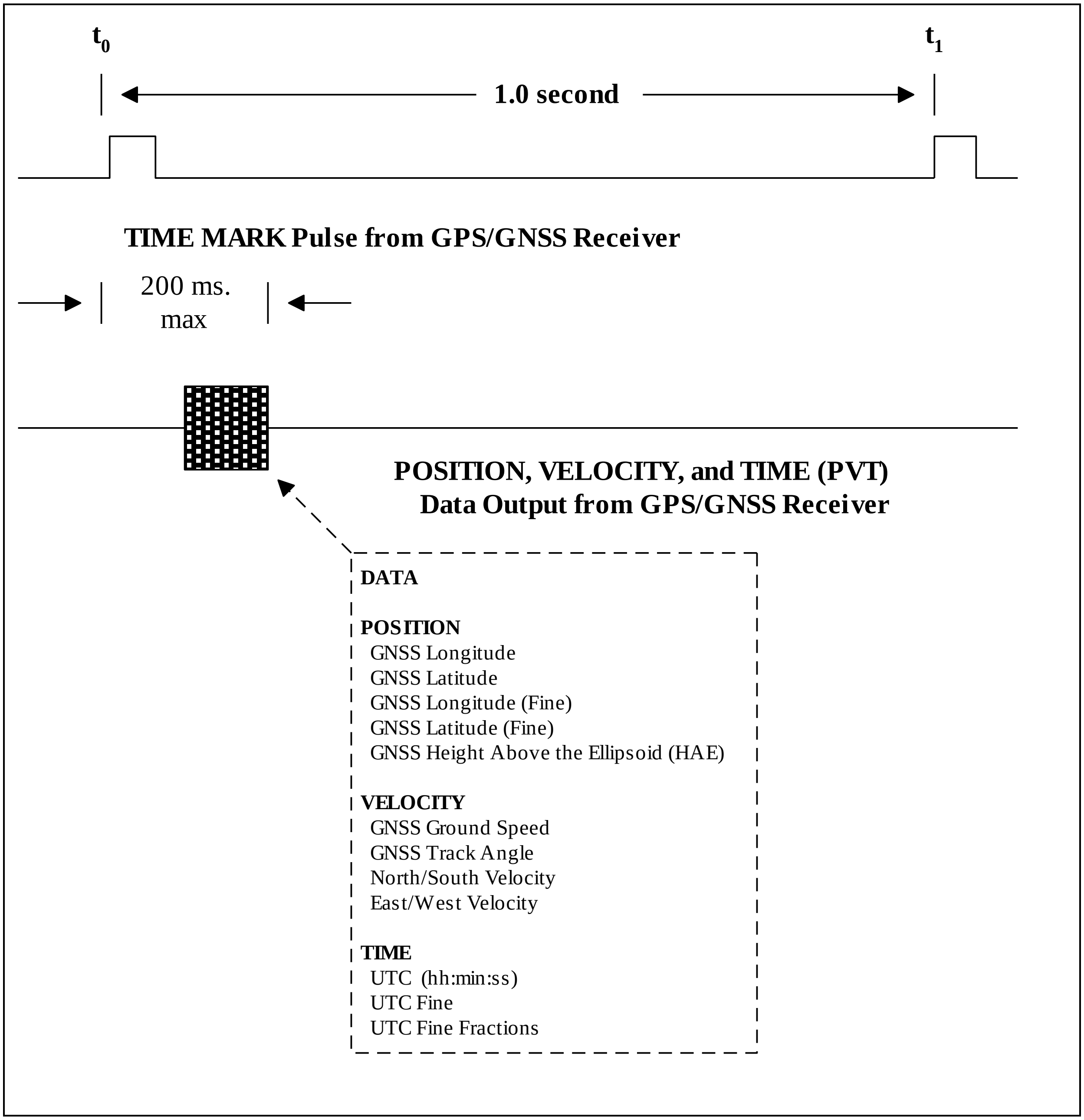
(1). Synchronize the loading of the Surface Position Message such that the register is properly loaded 100 milliseconds ±50 milliseconds prior to the time of applicability of the data being loaded into the register.

(2). Establish the “Time” subfield in ADS-B Surface Position Messages (see §2.2.3.2.4) as specified in §2.2.3.2.4.5,

(3). Establish the “CPR Format” subfield in ADS-B Surface Position Messages (see §2.2.3.2.4) as specified in §2.2.3.2.4.6,

(4). Extrapolate Surface Latitude Position in ADS-B Surface Position Messages (see §2.2.3.2.4) as specified in §2.2.3.2.4.7.2, and

(5). Extrapolate Surface Longitude Position in ADS-B Surface Position Messages (see §2.2.3.2.4) as specified in §2.2.3.2.4.8.2.



<u>Figure 2-15:</u> GPS/GNSS Time Mark Pulse

<u>Note:</u> *Navigation and UTC time information should be available within 200 milliseconds following the leading edge of the Time Mark at time t_0. The information is considered to be valid at time t_0. Specifically, the information is NOT projected to be valid at time t_1, which represents the beginning of the next GPS/GNSS Epoch.*

2.2.5.1.7 Own Position Latitude Data

The ADS-B Transmitting Subsystem **shall** accept own position Latitude information via an appropriate variable data input interface and use such data to establish subfields in ADS-B transmitted messages as follows:

a. The encoded Latitude subfield in the Airborne Position Message (see §2.2.3.2.3) as specified in §2.2.3.2.3.7 through §2.2.3.2.3.7.4,

b. The encoded Latitude subfield in the Surface Position Message (see §2.2.3.2.4) as specified in §2.2.3.2.4.7 through §2.2.3.2.4.7.4,

Note: *Encoded Latitude for the Airborne and the Surface Position Messages will normally not be the same. However, the procedures used to obtain the Encoded Latitude for either case are essentially the same in the CPR algorithm. (See Appendix A).*

c. If Latitude data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the Encoded Latitude subfield of the Airborne Position Message (§2.2.3.2.3) when airborne or into the Encoded Latitude subfield of the Surface Position Message (§2.2.3.2.4) when on the surface.

Note: *Any airport surface application(s) that will use ADS-B surface position information will need to account for the potential navigation error associated with the reported position relative to the navigation center of the aircraft.*

2.2.5.1.8 Own Position Longitude Data

The ADS-B Transmitting Subsystem **shall** accept own position Longitude information via an appropriate variable data input interface and use such data to establish subfields in ADS-B transmitted messages as follows:

a. The encoded Longitude subfield in the Airborne Position Message (see §2.2.3.2.3) as specified in §2.2.3.2.3.8 through §2.2.3.2.3.8.4,

b. The encoded Longitude subfield in the Surface Position Message (see §2.2.3.2.4) as specified in §2.2.3.2.4.8 through §2.2.3.2.4.8.4,

Note: *Encoded Longitude for the Airborne and the Surface Position Messages will normally not be the same. However, the procedures used to obtain the Encoded Longitude for either case are essentially the same in the CPR algorithm. (See Appendix A).*

c. If Longitude data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the Encoded Longitude subfield of the Airborne Position Message (§2.2.3.2.3) when airborne or into the Encoded Longitude subfield of the Surface Position Message (§2.2.3.2.4) when on the surface.

Note: *Any airport surface application(s) that will use ADS-B surface position information will need to account for the potential navigation error associated with the reported position relative to the navigation center of the aircraft.*

2.2.5.1.9 Ground Speed Data

a. The ADS-B Transmitting Subsystem **shall** accept own vehicle Ground Speed information via an appropriate variable data input interface and use such data to establish the "Movement" subfield (see §2.2.3.2.4.2) in the Surface Position Message as specified in §2.2.3.2.4.2.

b. If Ground Speed data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the Movement subfield specified in §2.2.3.2.4.2.

c. Ground Speed may be used in conjunction with Ground Track data to arithmetically establish East/West Velocity Data (see §2.2.5.1.2) and North/South Velocity Data (see §2.2.5.1.3) if East/West and/or North/South Velocity Data is not available.

   (1). When Ground Speed data is used as provided in subparagraph "c," the NAC_V (see §2.2.5.1.19) data reported by the ADS-B Transmitting Subsystem **shall** be consistent with the accuracy, range, and resolution that can be obtained by using Ground Speed data as the input data to the arithmetic computations necessary.

   (2). When Ground Speed data is used as provided in subparagraph "c," but Ground Speed Data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into all transmitted subfields that are computed based on Ground Speed data.

2.2.5.1.10 Heading/Ground Track Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Heading/Ground Track information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Status Bit for Heading/Ground Track" subfield in the Surface Position Message (See §2.2.3.2.4) as specified in §2.2.3.2.4.3,

b. The "Heading/Ground Track" subfield in the Surface Position Message (see §2.2.3.2.4.2) as specified in §2.2.3.2.4.4,

c. If Heading/Ground Track data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the "Status Bit for Heading/Ground Track" and "Heading" subfields specified in §2.2.3.2.4.3 and §2.2.3.2.4.4 respectively,

d. Heading/Ground Track may be used in conjunction with Ground Speed data to arithmetically establish East/West Velocity Data (see §2.2.5.1.2) and North/South

Velocity Data (see §2.2.5.1.3) if East/West and/or North/South Velocity Data is not available.

(1). When Heading/Ground Track data is used, the NAC_V (see §2.2.5.1.19) data reported by the ADS-B Transmitting Subsystem **shall** be consistent with the accuracy, range, and resolution that can be obtained by using Heading data as the input data to the arithmetic computations necessary.

(2). When Heading/Ground Track data is used, but Heading/Ground Track Data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into all transmitted subfields that are computed based on Heading/Ground Track data.

<u>Notes:</u>

1. *Ground Track data may be unreliable at low ground speeds. At very low ground speeds, the best estimate of an aircraft's or ground vehicle's ground track angle may be from a heading source rather than from the "track angle" output of a GNSS receiver.*

2. *If a source of A/V Heading **is not** available to the ADS-B Transmitting Subsystem, but a source of Ground Track angle **is** available, then Ground Track angle may be used instead of Heading, <u>provided</u> that the "Status Bit for Heading/Ground Track" subfield is set to ZERO whenever the Ground Track angle is not a reliable indication of the A/V's heading. (The Ground Track angle is not a reliable indication of the A/V's heading when the A/V's ground speed is close to ZERO.)*

2.2.5.1.11 Aircraft Identification (*or* Registration) Data

a. The ADS-B Transmitting Subsystem **shall** accept own vehicle Aircraft Identification Data via an appropriate data input interface and use such data to establish the Aircraft Identification or Flight Number Data in Aircraft Identification and Category Messages (see §2.2.3.2.5) as specified in §2.2.3.2.5.3.

b. When Aircraft Identification or Flight Number data specified in subparagraph a is not available or is not valid, the ADS-B Transmitting Subsystem **shall** accept own vehicle Aircraft Registration Character Data (N250DL, etc.) via an appropriate data input interface and use such data to establish the Aircraft Identification or Flight Number Data in Aircraft Identification and Category Messages (see §2.2.3.2.5) as specified in §2.2.3.2.5.3.

c. Only if Aircraft Identification or Flight Number Data, and Aircraft Registration Data is not available to the ADS-B Transmitting Subsystem, **shall** the device enter ALL ZEROs into the character fields specified in §2.2.3.2.5.3.

2.2.5.1.12 East/West Velocity Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle East/West Velocity information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Encoded Longitude" subfield in Airborne Position Messages (see §2.2.3.2.3) as specified in §2.2.3.2.3.8 through §2.2.3.2.3.8.4,

b. The "Encoded Longitude" subfield in Surface Position Messages (see §2.2.3.2.4) as specified in §2.2.3.2.4.8 through §2.2.3.2.4.8.4,

c. The "East/West Direction Bit" subfield in Airborne Velocity Messages - Subtypes "1 & 2" (see §2.2.3.2.6.1 and §2.2.3.2.6.2) as specified in §2.2.3.2.6.1.6 and §2.2.3.2.6.2.6 respectively,

d. The "East/West Velocity" subfield in Airborne Velocity Messages - Subtypes "1 & 2" (see §2.2.3.2.6.1 and §2.2.3.2.6.2 respectively) as specified in §2.2.3.2.6.1.7 and §2.2.3.2.6.2.7 respectively.

If East/West Velocity data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs in the E/W Direction Bit and E/W Velocity subfields specified in:

(1). §2.2.3.2.6.1.6 and §2.2.3.2.6.1.7, and

(2). §2.2.3.2.6.2.6 and §2.2.3.2.6.2.7, respectively.

2.2.5.1.13 North/South Velocity Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle North/South Velocity information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Encoded Latitude" subfield in Airborne Position Messages (see §2.2.3.2.3) as specified in §2.2.3.2.3.7 through §2.2.3.2.3.7.4,

b. The "Encoded Latitude" subfield in Surface Position Messages (see §2.2.3.2.4) as specified in §2.2.3.2.4.7 through §2.2.3.2.4.7.4,

c. The "North/South Direction Bit" subfield in Airborne Velocity Messages - Subtypes "1 & 2" (see §2.2.3.2.6.1 and §2.2.3.2.6.2) as specified in §2.2.3.2.6.1.8 and §2.2.3.2.6.2.8, respectively,

d. The "North/South Velocity" subfield in Airborne Velocity Messages - Subtypes "1 & 2" (see §2.2.3.2.6.1 and §2.2.3.2.6.2 respectively) as specified in §2.2.3.2.6.1.9 and §2.2.3.2.6.2.9, respectively.

If North/South Velocity data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs in the N/S Direction Bit and N/S Velocity subfields specified in:

(1). §2.2.3.2.6.1.8 and §2.2.3.2.6.1.9, and

(2). §2.2.3.2.6.2.8 and §2.2.3.2.6.2.9, respectively.

2.2.5.1.14 Vertical Rate Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Vertical Rate (Geometric ***AND/OR*** Barometric referenced) information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Source Bit for Vertical Rate" subfield in the Airborne Velocity - Subtype "1, 2, 3, & 4" Messages (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4 respectively) as specified in §2.2.3.2.6.1.10, §2.2.3.2.6.2.10, §2.2.3.2.6.3.10 and §2.2.3.2.6.4.10, respectively,

b. The "Sign Bit for Vertical Rate" subfield in the Airborne Velocity - Subtype "1,2,3, & 4" Messages (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4 respectively) as specified in §2.2.3.2.6.1.11, §2.2.3.2.6.2.11, §2.2.3.2.6.3.11 and §2.2.3.2.6.4.11, respectively,

c. The "Vertical Rate" subfield in the Airborne Velocity - Subtype "1,2,3, & 4" Messages (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4 respectively) as specified in §2.2.3.2.6.1.12, §2.2.3.2.6.2.12, §2.2.3.2.6.3.12 and §2.2.3.2.6.4.12, respectively.

If Vertical Rate data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs in the "Source Bit for Vertical Rate," "Sign Bit for Vertical Rate," and "Vertical Rate" Subfields specified in subparagraphs a, b and c given directly above.

2.2.5.1.15 Heading (True or Magnetic) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Heading information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Heading Status" subfield in Airborne Velocity - Subtype "3 & 4" (§2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.6 and §2.2.3.2.6.4.6, respectively,

b. The "Heading" subfield in Airborne Velocity - Subtype "3 & 4" (§2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.7 and §2.2.3.2.6.4.7, respectively.

If Heading data is not available to the ADS-B Transmitting Subsystem, then the device **shall** enter ALL ZEROs into the "Heading Status Bit" and "Heading" subfields specified in subparagraphs a. and b. directly above respectively.

2.2.5.1.16 True Airspeed Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle True Airspeed information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Airspeed Type" subfield in Airborne Velocity - Subtype "3 & 4" (§2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.8 and §2.2.3.2.6.4.8, respectively,

b. The "Airspeed" subfield in Airborne Velocity - Subtype "3 & 4" (§2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.9 and §2.2.3.2.6.4.9, respectively.

If appropriate "True Airspeed" or "Indicated Airspeed" (§2.2.5.1.17) data is not available to the ADS-B Transmitting Subsystem, then the device **shall** set the "Airspeed Type," and "Airspeed" subfields to ALL ZEROs in the subfields specified in:

(1). §2.2.3.2.6.3.8, and §2.2.3.2.6.3.9, and

(2). §2.2.3.2.6.4.8, and §2.2.3.2.6.4.9.

2.2.5.1.17 Indicated Airspeed Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Indicated Airspeed information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "Airspeed Type" subfield in Airborne Velocity - Subtype "3 & 4" (§2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.8 and §2.2.3.2.6.4.8, respectively,

b. The "Airspeed" subfield in Airborne Velocity - Subtype "3 & 4" (§2.2.3.2.6.3 and §2.2.3.2.6.4) as specified in §2.2.3.2.6.3.9 and §2.2.3.2.6.4.9 respectively,

If appropriate "True Airspeed" (§2.2.5.1.16) or "Indicated Airspeed" data is not available to the ADS-B Transmitting Subsystem, then the device **shall** set the "Airspeed Type," and "Airspeed" subfields to ALL ZEROs in the subfields specified in:

(1). §2.2.3.2.6.3.8 and §2.2.3.2.6.3.9, and

(2). §2.2.3.2.6.4.8 and §2.2.3.2.6.4.9.

2.2.5.1.18 Intent Change Data

a. Intent Change data necessary to establish the setting of the "Intent Change Flag" in Airborne Velocity - Subtype "1, 2, 3, & 4" Messages (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4, respectively) is a Mode-S Transponder function only. Therefore, appropriate requirements **shall** be established for such devices in RTCA DO-181D (EUROCAE ED-73C).

b. Non-Transponder-Based ADS-B Transmitting Subsystems need no additional data to establish the "Intent Change Flag" in Airborne Velocity - Subtype "1, 2, 3, & 4" Messages (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4, respectively) in accordance with §2.2.3.2.6.1.3, §2.2.3.2.6.2.3, §2.2.3.2.6.3.3 and §2.2.3.2.6.4.3, respectively.

2.2.5.1.19 NAC_V Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Navigation Accuracy Category - Velocity (NAC_V) information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Messages as follows:

a. The "NAC_V" subfield in the Airborne Velocity - Subtype "1, 2, 3, & 4" Messages (§2.2.3.2.6.1, §2.2.3.2.6.2, §2.2.3.2.6.3 and §2.2.3.2.6.4 respectively) as specified in §2.2.3.2.6.1.5, §2.2.3.2.6.2.5, §2.2.3.2.6.3.5 and §2.2.3.2.6.4.5, respectively,

b. If "NAC_V" data is not available to the ADS-B Transmitting Subsystem, then the device shall enter ALL ZEROs in the "NAC_V" subfields specified in §2.2.3.2.6.1.5, §2.2.3.2.6.2.5, §2.2.3.2.6.3.5 and §2.2.3.2.6.4.5.

2.2.5.1.20 Subtype (Aircraft Status) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Subtype information via an appropriate variable data input interface and use such data to establish the "Subtype" subfield in the Aircraft Operational Status Messages (see §2.2.3.2.7.2) as specified in §2.2.3.2.7.2.2.

If appropriate Subtype data is not available to the ADS-B Transmitting Subsystem, then the device **shall** set the "Subtype" subfield specified in §2.2.3.2.7.2.2 to ZERO.

2.2.5.1.21 Capability Class (Reserved) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "Reserved" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.22 Capability Class (UAT IN) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "UAT IN" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages as specified in §2.2.3.2.7.2.3.2.

2.2.5.1.23 Capability Class (1090ES IN) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "1090ES IN" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages as specified in §2.2.3.2.7.2.3.3.

2.2.5.1.24 Capability Class (ARV Report Capability) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "ARV Report Capability" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.25 Capability Class (TS Report Capability) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "TS Report Capability" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.26 Capability Class (TC Report Capability) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "TC Report Capability" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.27 Capability Class (Position Offset Applied) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "Position Offset Applied" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.28 Operational Mode (OM Format) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "OM Format" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.29 Operational Mode (TCAS/ACAS Resolution Advisory Active) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "TCAS/ACAS Resolution Advisory Active" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages (TYPE=31, Subtype=0) as specified in §2.2.3.2.7.2.4.2.

2.2.5.1.30 Operational Mode (IDENT Switch Active) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "IDENT Switch Active" information via an appropriate variable data input interface and use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.31 Operational Mode (Reserved for Receiving ATC Services) Data

The ADS-B Transmitting Subsystem **shall** be capable of accepting "Receiving ATC Services" information via an appropriate variable data input interface and, if required in a future version of these MOPS, use such data to establish subfields in transmitted ADS-B Aircraft Operational Status Messages.

2.2.5.1.32 Radio Altitude Data

The ADS-B Transmitting Subsystem **shall** accept Radio Altitude via an appropriate variable data input interface and use such data to establish the "Air/Ground" state and thereby the "CA" field as provided in §2.2.3.2.1.2.

2.2.5.1.33 Version Number Data

ADS-B Transmitting Subsystems **shall** set the Version Number as indicated in Table 2-69.

2.2.5.1.34 Navigation Accuracy Category for Position (NAC_P) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle NAC_P information via an appropriate variable data input interface and use such data to establish the "NAC_P" subfield transmitted in the ADS-B Target State and Status Message as specified in §2.2.3.2.7.1.3.8, and the "NAC_P" subfield transmitted in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.7.

2.2.5.1.35 Navigation Integrity Category for Barometric Altitude (NIC_{BARO}) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle NIC_{BARO} information via an appropriate variable data input interface and use such data to establish the "NIC_{BARO}" subfield transmitted in the ADS-B Target State and Status Message as specified in §2.2.3.2.7.1.3.9, and the "NIC_{BARO}" subfield transmitted in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.10.

2.2.5.1.36 Navigation Integrity Category Supplement (NIC_{SUPP}) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Navigation Integrity Catgeory Supplement (NIC_{SUPP}) information via an appropriate variable data input interface and use such data to establish the "NIC_{SUPP}" subfield transmitted in the ADS-B Airborne Position Message as specified in §2.2.3.2.3.3, and in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.6.

2.2.5.1.37 A/V Length/Width Code Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle A/V Length/Width Code information via an appropriate variable data input interface and use such data to establish the "A/V Length/Width Code" subfield transmitted in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.11.

2.2.5.1.38 Track Angle/Heading Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Track Angle/Heading information via an appropriate variable data input interface and use such data to establish the "Track Angle/Heading" subfield transmitted in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.12.

2.2.5.1.39 Horizontal Reference Direction (HRD) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle HRD information via an appropriate variable data input interface and use such data to establish the "HRD" subfield transmitted in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.13.

2.2.5.1.40 Source Integrity Level (SIL) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Source Integrity Level information via an appropriate variable data input interface and use such data to establish the "SIL" subfield transmitted in the ADS-B Target State and Status Message as specified in §2.2.3.2.7.1.3.10, and the "SIL" subfield transmitted in the ADS-B Operational Status Message as specified in §2.2.3.2.7.2.9.

2.2.5.1.41 SIL Supplement Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Source Integrity Level Supplement (SIL_{SUPP}) information via an appropriate data input interface and use such data to establish the "SIL_{SUPP}" subfield transmitted in the ADS-B Target State and Status Message as specified in §2.2.3.2.7.1.3.1, and the "SIL_{SUPP}" subfield transmitted in the ADS-B Aircraft Operational Status Message as specified in §2.2.3.2.7.2.14.

Note: *Section §2.2.3.2.7.1.3.1 indicates that an input interface may not be necessary to provide SIL Supplement information. Rather, it should be sufficient to establish that the SIL Supplement is set to "ZERO" (0) if a GNSS source is being used to provide the geometric position information used to establish position in the Airborne and Surface Position Messages. Likewise, it should be sufficient to establish that the SIL Supplement is set to "ONE" (1) if a NON-GNSS source is being used to provide the geometric position information used to establish position in the Airborne and Surface Position Messages. Typical Non-GNSS sources are recognized as IRS, IRU, DME/DME, DME/DME/LOC, etc.*

2.2.5.1.42 MCP/FCU Selected Altitude or FMS Selected Altitude Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle MCP/FCU Selected Altitude or FMS Selcetd Altitude information via an appropriate variable data input interface and use such data to establish the "MCP/FCU Selected Altitude or FMS Selcetd Altitude" subfield transmitted in the ADS-B Target State and Status Message as specified in §2.2.3.2.7.1.3.3.

2.2.5.1.43 Barometric Pressure Setting (Minus 800 millibars) Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Barometric Pressure Setting (Minus 800 millibars) information via an appropriate variable data input interface and use such data to establish the "Barometric Pressure Setting (Minus 800 millibars)" subfield transmitted in the ADS-B Target State and Status Message as specified in §2.2.3.2.7.1.3.4.

2.2.5.1.44 Selected Heading Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Selected Heading information via an appropriate variable data input interface and use such data to establish subfields transmitted in the ADS-B Target State and Status Message as follows:

a. The "Selected Heading Status" subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.5,

b. The "Selected Heading Sign" subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.6, and

c. The "Selected Heading" subfield in Target State and Status Messages as specified in §2.2.3.2.7.1.3.7.

2.2.5.1.45 MCP / FCU Mode Bits Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle MCP/FCU Mode information via an appropriate variable data input interface and use such data to establish the subfields transmitted in the ADS-B Target State and Status Message as follows:

a. The "Status of MCP/FCU Mode Bits" subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.11,

b. The “Autopilot Engaged” subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.12,

c. The “VNAV Mode Engaged” subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.13,

d. The “Altitude Hold Mode” subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.14,

e. The “Approach Mode” subfield in the Target State and Status Message as specified in §2.2.3.2.7.1.3.16.

2.2.5.1.46 Emergency/Priority Status Data

The ADS-B Transmitting Subsystem **shall** accept own vehicle Emergency/Priority Status information via an appropriate variable data input interface and use such data to establish the “Emergency/Priority Status” subfield transmitted in the “Emergency/Priority Status” subfield transmitted in the ADS-B Extended Squitter Aircraft Status Message as specified in §2.2.3.2.7.8.

2.2.5.1.47 Mode A (4096) Code

The ADS-B Transmitting Subsystem **shall** accept the own vehicle Mode A (4096) Code from the transponder function and use such data to establish the Mode A Code subfield transmitted in the ADS-B Extended Squitter Aircraft Status Message (TYPE=28, Subtype=1) Message as specified in §2.2.3.2.7.8.1.

2.2.5.1.48 TCAS Operational Data

The ADS-B Transmitting Subsystem **shall** accept TCAS Operational data via an appropriate variable data input interface and use such data to establish the subfield transmitted in the ADS-B Extended Squitter Target State and Status Message (TYPE=29, Subtype=1) as specified in §2.2.3.2.7.1.3.17 and the Aircraft Operational Status Message, as specified in §2.2.3.2.7.2.3.2.

2.2.5.1.49 Single Antenna Flag Data

The ADS-B Transmitting Subsystem **shall** accept Single Antenna Operation information via an appropriate data input interface and use such data to establish the subfield transmitted in the ADS-B Extended Squitter Aircraft Operational Status Message (TYPE=31, Subtype=0) as specified in §2.2.3.2.7.2.4.5.

2.2.5.1.50 System Design Assurance (SDA) Data

The ADS-B Transmitting Subsystem **shall** accept System Design Assurance (SDA) information via an appropriate data input interface and use such data to establish the subfield transmitted in the ADS-B Extended Squitter Aircraft Operational Status Message (TYPE=31, Subtype=0) as specified in §2.2.3.2.7.2.4.6.

2.2.5.1.51 GNSS Vertical Figure of Merit (VFOM) Data

The ADS-B Transmitting Subsystem **shall** accept GNSS Vertical Figure of Merit (VFOM) information via an appropriate data input interface and use such data to establish the Geometric Vertical Accuracy (GVA) subfield transmitted in the ADS-B Extended Squitter Aircraft Operational Status Message (TYPE=31, Subtype=0) as specified in §2.2.3.2.7.2.8.

2.2.5.2 ADS-B Transmission Device Message Latency

2.2.5.2.1 Airborne Position Message Latency

The ADS-B Transmission Device Message Processor function **shall** update the Airborne Position Message data fields specified in §2.2.3.2.3 as follows:

a. Type information may change due to changes in the precision, quality, or integrity of received navigation information. As such, any change in the TYPE information identified in §2.2.3.2.3.1, or in the NIC Supplement information identified in §2.2.3.2.3.3, **shall** be reflected in the TYPE subfield of the next scheduled Airborne Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission.

b. Any change in the Surveillance Status identified in §2.2.3.2.3.2 **shall** be reflected in the Surveillance Status subfield of the next scheduled Airborne Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission.

c. Any change in the Altitude identified in §2.2.3.2.3.4 **shall** be reflected in the Altitude subfield of the next scheduled Airborne Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission.

d. CPR Format changes at 0.2 second intervals or more often as specified in §2.2.3.2.3.6. A change in the CPR Format **shall** be reflected in the CPR Format subfield of the next scheduled Airborne Position Message transmission provided that the change occurs at least ***"X"*** milliseconds prior to the next scheduled Airborne Position Message transmission. The time ***"X,"*** **shall** be dependent upon the NAC_P (see Table 2-71, §2.2.3.2.7.2.7 and §2.2.8.2.12) provided to the transmission device as follows:

   (1). ***"X"*** is equal to 200 milliseconds if $NAC_P \leq 8$

   (2). ***"X"*** is equal to 50 milliseconds if $NAC_P > 8$

Note: *All efforts must be made to allocate the time necessary to update the actual transmission buffer within the 200 millisecond time frame allocated to the CPR Format changes. That is that no additional time can be added to the 200 milliseconds already allocated.*

e. Encoded Latitude (specified in §2.2.3.2.3.7) must be extrapolated in accordance with §2.2.3.2.3.7.2 for precision systems. Likewise, Encoded Latitude must be updated in accordance with §2.2.3.2.3.7.3 for non-precision systems. Any change in the Encoded Latitude **shall** be reflected in the Encoded Latitude subfield of the next scheduled Airborne Position Message transmission provided that the change occurs at least ***"X"*** milliseconds prior to the next scheduled Airborne Position Message transmission. The time ***"X,"*** **shall** be dependent upon the NAC_P (see Table 2-71, §2.2.3.2.7.2.7 and §2.2.8.2.12) provided to the transmission device as follows:

(1). ***"X"*** is equal to 200 milliseconds if $NAC_P \leq 8$

(2). ***"X"*** is equal to 50 milliseconds if $NAC_P > 8$

Note: *All efforts must be made to allocate the time necessary to update the actual transmission buffer within the 200 millisecond time frame allocated updating the Encoded Latitude. That is, that no additional time can be added to the 200 milliseconds already allocated*

f. Encoded Longitude (specified in §2.2.3.2.3.8) must be extrapolated in accordance with §2.2.3.2.3.8.2 for precision systems. Likewise, Encoded Longitude must be updated in accordance with §2.2.3.2.3.8.3 for non-precision systems. Any change in the Encoded Longitude **shall** be reflected in the Encoded Longitude subfield of the next scheduled Airborne Position Message transmission provided that the change occurs at least ***"X"*** milliseconds prior to the next scheduled Airborne Position Message transmission. The time ***"X,"*** **shall** be dependent upon the NAC_P (see Table 2-71, §2.2.3.2.7.2.7 and §2.2.8.2.12) provided to the transmission device as follows:

(1). ***"X"*** is equal to 200 milliseconds if $NAC_P \leq 8$

(2). ***"X"*** is equal to 50 milliseconds if $NAC_P > 8$

Note: *All efforts must be made to allocate the time necessary to update the actual transmission buffer within the 200 millisecond time frame allocated updating the Encoded Latitude. That is, that no additional time can be added to the 200 milliseconds already allocated*

2.2.5.2.2 Surface Position Message Latency

The ADS-B Transmission Device Message Processor function **shall** update the Surface Position Message data fields specified in §2.2.3.2.4 as follows:

a. Type information may change due to changes in the precision, quality, or integrity of received navigation information. As such, any change in the TYPE information identified in §2.2.3.2.4.1 **shall** be reflected in the Type subfield of the next scheduled Surface Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission.

b. Any change in Movement (i.e., Ground Speed) identified in §2.2.3.2.4.2 **shall** be reflected in the Movement subfield of the next scheduled Surface Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission.

c. Any change in Ground Track identified in §2.2.3.2.4.3 and §2.2.3.2.4.4 **shall** be reflected in the appropriate Ground Track subfields of the next scheduled Surface Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission.

d. CPR Format changes at 0.2 second intervals as specified in §2.2.3.2.4.6. A change in the CPR Format **shall** be reflected in the CPR Format subfield of the next scheduled Surface Position Message transmission provided that the change occurs at least ***"X"*** milliseconds prior to the next scheduled Surface Position Message transmission. The time ***"X,"*** **shall** be dependent upon the NAC_P (see Table 2-71, §2.2.3.2.7.2.7 and §2.2.8.2.12) provided to the transmission device as follows:

(1). ***"X"*** is equal to 200 milliseconds if $NAC_P \leq 8$

(2). ***"X"*** is equal to 50 milliseconds if $NAC_P > 8$

Note: *All efforts must be made to allocate the time necessary to update the actual transmission buffer within the 200 millisecond time frame allocated to the CPR Format changes. That is that no additional time can be added to the 200 milliseconds already allocated.*

e. Encoded Latitude (specified in §2.2.3.2.4.7) must be extrapolated in accordance with §2.2.3.2.4.7.2 for precision systems. Likewise, Encoded Latitude must be updated in accordance with §2.2.3.2.4.7.3 for non-precision systems. Any change in the Encoded Latitude **shall** be reflected in the Encoded Latitude subfield of the next scheduled Surface Position Message transmission provided that the change occurs at least ***"X"*** milliseconds prior to the next scheduled Surface Position Message transmission. The time ***"X,"*** **shall** be dependent upon the NAC_P (see Table 2-71, §2.2.3.2.7.2.7 and §2.2.8.2.12) provided to the transmission device as follows:

(1). ***"X"*** is equal to 200 milliseconds if $NAC_P \leq 8$

(2). ***"X"*** is equal to 50 milliseconds if $NAC_P > 8$

Note: *All efforts must be made to allocate the time necessary to update the actual transmission buffer within the 200 millisecond time frame allocated updating the Encoded Latitude. That is, that no additional time can be added to the 200 milliseconds already allocated.*

f. Encoded Longitude (specified in §2.2.3.2.4.8) must be extrapolated in accordance with §2.2.3.2.4.8.2 for precision systems. Likewise, Encoded Latitude must be updated in accordance with §2.2.3.2.4.8.3 for non-precision systems. Any change in the Encoded Longitude **shall** be reflected in the Encoded Longitude subfield of the next scheduled Surface Position Message transmission provided that the change occurs at least ***"X"*** milliseconds prior to the next scheduled Surface Position Message transmission. The time ***"X,"*** **shall** be dependent upon the NAC_P (see Table 2-71, §2.2.3.2.7.2.7 and §2.2.8.2.12) provided to the transmission device as follows:

(1). ***"X"*** is equal to 200 milliseconds if $NAC_P \leq 8$

(2). ***"X"*** is equal to 50 milliseconds if $NAC_P > 8$

Note: *All efforts must be made to allocate the time necessary to update the actual transmission buffer within the 200 millisecond time frame allocated updating the Encoded Longitude. That is, that no additional time can be added to the 200 milliseconds already allocated.*

2.2.5.2.3 Aircraft Identification Message Latency

The ADS-B Transmission Device Message Processor function **shall** update the Aircraft Identification Message data fields specified in §2.2.3.2.5 as follows:

a. Type information for the Aircraft Identification Message should be fixed and therefore not change. However, if changes are imposed, any such change in the TYPE information identified in §2.2.3.2.5.1 **shall** be reflected in the Type subfield of the Aircraft Identification message once the data has been stable (i.e., no changes) for a period of 4 seconds.

b. ADS-B Emitter Category information for the Aircraft Identification Message should be fixed and therefore not change. However, if changes are imposed, any such change in the ADS-B Emitter Category information identified in §2.2.3.2.5.2 **shall** be reflected in the ADS-B Emitter Category subfield of the Aircraft Identification message once the data has been stable (i.e., no changes) for a period of 4 seconds.

c. Any change in Character information identified in §2.2.3.2.5.3 **shall** be reflected in the appropriate Character subfields of the Aircraft Identification message once the data has been stable (i.e., no changes) for a period of 4 seconds.

2.2.5.2.4 Airborne Velocity Message - Subtype=1 Latency

The ADS-B Transmission Device Message Processor function **shall** update the Airborne Velocity Message - Subtype=1 data fields specified in §2.2.3.2.6.1 as follows:

Any change in the data used to structure the following subfields of the Airborne Velocity Message - Subtype=1 **shall** be reflected in the affected subfield of the next scheduled Airborne Velocity Message - Subtype=1 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message - Subtype=1 transmission:

(1). TYPE – (§2.2.3.2.6.1.1)

(2). Subtype – (§2.2.3.2.6.1.2)

(3). Intent Change Flag – (§2.2.3.2.6.1.3)

(4). NAC_V -- (§2.2.3.2.6.1.5)

(5). East/West Direction Bit and East/West Velocity -- (§2.2.3.2.6.1.6 and §2.2.3.2.6.1.7)

(6). North/South Direction Bit and North/South Velocity -- (§2.2.3.2.6.1.8 and §2.2.3.2.6.1.9)

(7). Vertical Rate – (§2.2.3.2.6.1.10 through §2.2.3.2.6.1.12)

(8). Difference From Barometric Altitude – (§2.2.3.2.6.1.14 and §2.2.3.2.6.1.15)

2.2.5.2.5 Airborne Velocity Message - Subtype=2 Latency

The ADS-B Transmission Device Message Processor function **shall** update the Airborne Velocity Message - Subtype=2 data fields specified in §2.2.3.2.6.2 as follows:

Any change in the data used to structure the following subfields of the Airborne Velocity - Subtype=2 message **shall** be reflected in the affected subfield of the next scheduled Airborne Velocity - Subtype=2 message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity - Subtype=2 message transmission:

(1). TYPE – (§2.2.3.2.6.2.1)

(2). Subtype – (§2.2.3.2.6.2.2)

(3). Intent Change Flag – (§2.2.3.2.6.2.3)

(4). NAC_V -- (§2.2.3.2.6.2.5)

(5). East/West Direction Bit and East/West Velocity -- (§2.2.3.2.6.2.6 and §2.2.3.2.6.2.7)

(6). North/South Direction Bit and North/South Velocity -- (§2.2.3.2.6.2.8 and §2.2.3.2.6.2.9)

(7). Vertical Rate – (§2.2.3.2.6.2.10 through §2.2.3.2.6.2.12)

(8). Difference From Barometric Altitude – (§2.2.3.2.6.2.14 and §2.2.3.2.6.2.15)

2.2.5.2.6 Airborne Velocity Message - Subtype=3 Latency

The ADS-B Transmission Device Message Processor function **shall** update the Airborne Velocity Message - Subtype=3 data fields specified in §2.2.3.2.6.3 as follows:

Any change in the data used to structure the following subfields of the Airborne Velocity Message - Subtype=3 **shall** be reflected in the affected subfield of the next scheduled Airborne Velocity Message - Subtype=3 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message - Subtype=3 transmission:

(1). TYPE – (§2.2.3.2.6.3.1)

(2). Subtype – (§2.2.3.2.6.3.2)

(3). Intent Change Flag – (§2.2.3.2.6.3.3)

(4). NAC_V -- (§2.2.3.2.6.3.5)

(5). Heading -- (§2.2.3.2.6.3.6 through §2.2.3.2.6.3.7)

(6). Airspeed -- (§2.2.3.2.6.3.8 and §2.2.3.2.6.3.9)

(7). Vertical Rate – (§2.2.3.2.6.3.10 through §2.2.3.2.6.3.12)

(8). Difference From Barometric Altitude – (§2.2.3.2.6.3.14 and §2.2.3.2.6.3.15)

2.2.5.2.7 Airborne Velocity Message - Subtype=4 Latency

The ADS-B Transmission Device Message Processor function **shall** update the Airborne Velocity Message - Subtype=4 data fields specified in §2.2.3.2.6.4 as follows:

Any change in the data used to structure the following subfields of the Airborne Velocity Message - Subtype=4 **shall** be reflected in the affected subfield of the next scheduled Airborne Velocity Message - Subtype=4 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message - Subtype=4 transmission:

(1). TYPE – (§2.2.3.2.6.4.1)

(2). Subtype – (§2.2.3.2.6.4.2)

(3). Intent Change Flag – (s§2.2.3.2.6.4.3)

(4). NAC_V -- (§2.2.3.2.6.4.5)

(5). Heading -- (§2.2.3.2.6.4.6 through §2.2.3.2.6.4.7)

(6). Airspeed -- (§2.2.3.2.6.4.8 and §2.2.3.2.6.4.9)

(7). Vertical Rate – (§2.2.3.2.6.4.10 through §2.2.3.2.6.4.12)

(8). Difference From Barometric Altitude - (§2.2.3.2.6.4.14 and §2.2.3.2.6.4.15)

2.2.5.2.8 Airborne Velocity Message - Subtype “5” Latency

RESERVED FOR FUTURE APPLICATION.

2.2.5.2.9 Airborne Velocity Message - Subtype “6” Latency

RESERVED FOR FUTURE APPLICATION

2.2.5.2.10 Airborne Velocity Message - Subtype “7” Latency

RESERVED FOR FUTURE APPLICATION

2.2.5.2.11 Target State and Status Message Latency

The ADS-B Transmission Device Message Processor function **shall** update the Target State and Status Message data fields specified in §2.2.3.2.7.1 as follows:

Any change in the data used to structure the following subfields of the Target State and Status Message **shall** be reflected in the affected subfield of the next scheduled Target State and Status Message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Target State Message transmission.

(1). TYPE – (§2.2.3.2.7.1.1)

(2). Subtype (§2.2.3.2.7.1.2)

(3). SIL Supplement (§2.2.3.2.7.1.3.1)

(4). Selected Altitude Type (§2.2.3.2.7.1.3.2)

(5). MCP/FCU Selected Altitude or FMS Selected Altitude (§2.2.3.2.7.1.3.3)

(6). Barometric Pressure Setting (Minus 800 millibars) (§2.2.3.2.7.1.3.4)

(7). Selected Heading Status (§2.2.3.2.7.1.3.5)

(8). Selected Heading Sign (§2.2.3.2.7.1.3.6)

(9). Selected Heading (§2.2.3.2.7.1.3.7)

(10). NAC_P (§2.2.3.2.7.1.3.8)

(11). NIC_{BARO} (§2.2.3.2.7.1.3.9)

(12). SIL (§2.2.3.2.7.1.3.10)

(13). Status of MCP/FCU Mode Bits (§2.2.3.2.7.1.3.11)

(14). Autopilot Engaged (§2.2.3.2.7.1.3.12)

(15). VNAV Mode Engaged (§2.2.3.2.7.1.3.13)

(16). Altitude Hold Mode (§2.2.3.2.7.1.3.14)

(17). Approach Mode (§2.2.3.2.7.1.3.16)

(18). TCAS Operational (§2.2.3.2.7.1.3.17)

<u>Note:</u> *In the future, the ADS-B system may need to be capable of processing Target State and Status Messages that are independent of each other, as identified with different Subtype codes. Likewise, the latency requirements for each message Subtype will need to be satisfied in an independent manner.*

2.2.5.2.12 Aircraft Operational Status Message Latency

The ADS-B Transmission Device Message Processor function **shall** update the Aircraft Operational Status Message data fields specified in §2.2.3.2.7.2 as follows:

Any change in the data used to structure the following subfields of the Aircraft Operational Status Message **shall** be reflected in the affected subfield of the next scheduled Aircraft Operational Status Message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission:

(1). TYPE Code – (§2.2.3.2.7.2.1)

(2). Subtype Code – (§2.2.3.2.7.2.2)

(3). Capability Class – (§2.2.3.2.7.2.3 through §2.2.3.2.7.2.3.11)

(4). Operational Mode – (§2.2.3.2.7.2.4 through §2.2.3.2.7.2.4.7)

(5). Version Number (§2.2.3.2.7.2.5)

(6). NIC Supplement-A (§2.2.3.2.7.2.6)

(7). NAC_P (§2.2.3.2.7.2.7)

(8). Geometric Vertical Accuracy (§2.2.3.2.7.2.8)

(9). SIL (§2.2.3.2.7.2.9)

(10). NIC_{BARO} (§2.2.3.2.7.2.10)

(11). Aircraft Length and Width Codes (§2.2.3.2.7.2.11)

(12). Track Angle/Heading (§2.2.3.2.7.2.12)

(13). Horizontal Reference Direction (HRD) (§2.2.3.2.7.2.13)

(14). SIL Supplement (§2.2.3.2.7.2.14)

2.2.5.2.13 TYPE 23 TEST Message Latency

The ADS-B Transmission Device Message Processor **shall** process Vendor Specified data for ADS-B Test messages specified in §2.2.3.2.7.3 with any change in data being reflected in the next scheduled TYPE 23 Test Event-Driven Message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled TYPE 23 Test Event-Driven Message transmission.

2.2.5.2.14 TYPE 24 Message Latency

Reserved for Future Application.

2.2.5.2.15 TYPE 25 Message Latency

Reserved for Future Application.

2.2.5.2.16 TYPE 26 Message Latency

Reserved for Future Application.

2.2.5.2.17 TYPE 27 Message Latency

Reserved for future use of Trajectory Change.

2.2.5.2.18 Aircraft Status Message – Subtype=1 Latency

The ADS-B Transmission Device Message Processor function **shall** update the Aircraft Status Message – Subtype=1 data fields specified in §2.2.3.2.7.8.1 as follows:

Any change in the data used to structure the following subfields of the Aircraft Status Message – Subtype=1 (Emergency/Priority Status) **shall** be reflected in the affected subfield of the next scheduled Aircraft Status Message – Subtype=1 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Aircraft Status Message – Subtype=1 transmission.

(1). TYPE – (§2.2.3.2.6.1.1)

(2). Subtype – (§2.2.3.2.6.1.2)

(3). EMERGENCY/PRIORITY STATUS FLAG – (§2.2.3.2.7.1.3.12)

2.2.5.2.19 Aircraft Status Message – Subtype=2 Latency

The ADS-B Transmission Device Message Processor function **shall** update the Aircraft Status Message – Subtype=2 data fields specified in §2.2.3.2.7.8.2 as follows:

Any change in the data used to structure the following subfields of the Aircraft Status Message – Subtype=2 (TCAS Resolution Advisory Broadcast) **shall** be reflected in the affected subfield of the next scheduled Aircraft Status Message – Subtype=2 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Aircraft Status Message – Subtype=2 transmission.

(1). TYPE – (§2.2.3.2.6.1.1)

(2). Subtype – (§2.2.3.2.6.1.2)

(The following data items are defined in ICAO Annex 10, Vol IV, §4.3.8.4.2.2)

(3). ACTIVE RESOLUTION ADVISORIES

(4). RACs RECORD

(5). RA TERMINATED

(6). MULTIPLE THREAT ENCOUNTER

(7). THREAT – TYPE INDICATOR

(8). THREAT IDENTITY DATA

2.2.5.3 ADS-B Transmission Device Source Selection

When more than one position source is provided to the ADS-B transmitter, the transmitter **shall** select a single source to provide position, velocity, and quality metrics. Heading on the surface is an exception to this.

Notes:

1. *The source selection logic should be designed to prevent the selection from alternating between valid sources. One acceptable way to ensure this is to allow the source selection to switch sources only after an alternate source has consistently exceeded the performance of the currently selected source for several seconds.*

2. *Source selection logic may include criteria specific to the sources available on the aircraft. In general, sources that support higher integrity should be selected over sources that support lower integrity. When selecting among equivalent integrity sources, the source with the smallest Radius of Containment should be selected.*

2.2.6 ADS-B Receiving Device Message Processor Characteristics

To provide maximum flexibility in user application implementation of ADS-B information, ADS-B Receiving Devices are categorized into two major functional types, which are illustrated in Figure 2-16 and specified in the following subparagraphs.

Note: *Figure 2-19 provides additional detail in regards to ADS-B Message and Report general data flow.*

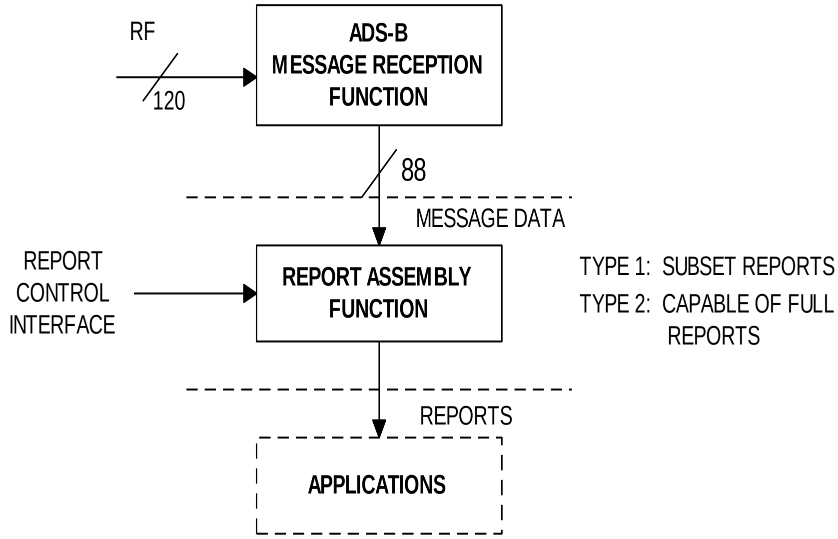


Figure 2-16: ADS-B Receiver / Report Assembly Functional Types

a. The ADS-B Message processing function begins with the ADS-B Message Reception Function receiving the transmitted message and then performing the necessary processing to deliver "Message Data" to the Report Assembly Function.

b. **TYPE 1** – TYPE 1 ADS-B Report Assembly subsystems are those that receive ADS-B Messages and produce application-specific subsets of ADS-B reports. As such, the Type 1 ADS-B Report Assembly subsystems may be customized to the particular applications using ADS-B reports. In addition, Type 1 ADS-B Report Assembly subsystems may be controlled by an external entity to produce installation-defined subsets of the reports that those subsystems are capable of producing.

c. **TYPE 2** – TYPE 2 ADS-B Report Assembly subsystems are those that receive ADS-B Messages and are capable of producing complete ADS-B reports in accordance with the applicable ADS-B equipment class requirements. Type 2 Report Assembly subsystems may be controlled by an external entity to produce installation-defined subsets of the reports that those subsystems are capable of producing.

2.2.6.1 ADS-B Message Reception Function Requirements

a. The ADS-B Message Reception Function **shall** properly decode valid ADS-B transmitted messages while ignoring other similar Mode-S transmissions.

b. The ADS-B Message Reception Function **shall** decode ADS-B transmitted messages in accordance with the requirements provided in §2.2.4.3.4.7 of this document.

The ADS-B Message Reception Function **shall** receive and decode ADS-B messages that are transmitted in Version Two (2) message formats as defined by §2.2.3.2 and its subparagraphs and also Airborne Position, Surface Position, Airborne Velocity, Aircraft Status, and Aircraft Operational Status, Identification and Category Messages that are transmitted in Version Zero (0) and Version One (1) message formats as defined by Appendix N, Section N.2, and its subparagraphs.

The version determined from the decoding of the Version Number subfield of the Aircraft Operational Status Message (§2.2.3.2.7.2.5) **shall** be retained and associated with the specific target. This Version Number **shall** then be used for determining the applicable message formats to be applied for the decoding of all subsequent 1090 MHz ADS-B Messages received from that target.

Notes:

1. *A summary of the RTCA DO-260 compliant, ADS-B Version Zero (0) and RTCA DO-260A compliant ADS-B Version One (1) Message formats that must be received and processed by Version Two (2) 1090 MHz ADS-B Receiving Subsystems is provided in Appendix N.*

2. *The Version Two (2) and Version One (1) Aircraft Operational Status Message format includes an explicit Version Number subfield ("ME" bits 41 – 43). For an ADS-B Version Zero (0) Aircraft Operational Status Message, these same bits were unassigned and were required to be set to a value of ZERO (binary 000). Thus, a Version Two (2) and Version One (1) ADS-B Receiving Subsystem will decode "ME" bits 41 – 43 received from a 1090 MHz ADS-B Transmitting Subsystem compliant with RTCA DO-260 to indicate a Version Number of Zero (0).*

2.2.6.1.1 ADS-B Message Reception Function Output Message Structure Requirements

All ADS-B Messages are received in the general format provided in Figure 2-2 and specified in §2.2.3.2.

Each ADS-B Message received **shall** be structured into the baseline ***OUTPUT MESSAGE*** shown in Figure 2-17 for delivery to the user interface or the Report Assembly function:

ADS-B Output Message Format Structure			
Transmitted Message BIT #	1 --- 5	9 ---------- 32	33 ----------------------------- 88
Output Message BIT #	1 --- 5	6 ---------- 29	30 ----------------------------- 85
FIELD NAME	**DF [5]**	**AA [24]**	**ME [56]**
	MSB LSB	MSB LSB	MSB LSB

Note: *"[#]" Provided in the FIELD indicates the number of bits in the field.*

Figure 2-17: ADS-B Output Message Format Structure

2.2.6.1.2 ADS-B and TIS-B Message Reception Function Output Message Delivery Requirements

Figure 2-18 illustrates the transmitted message receipt capabilities and the ***OUTPUT MESSAGE*** delivery requirements, which are specified in the following subparagraphs:

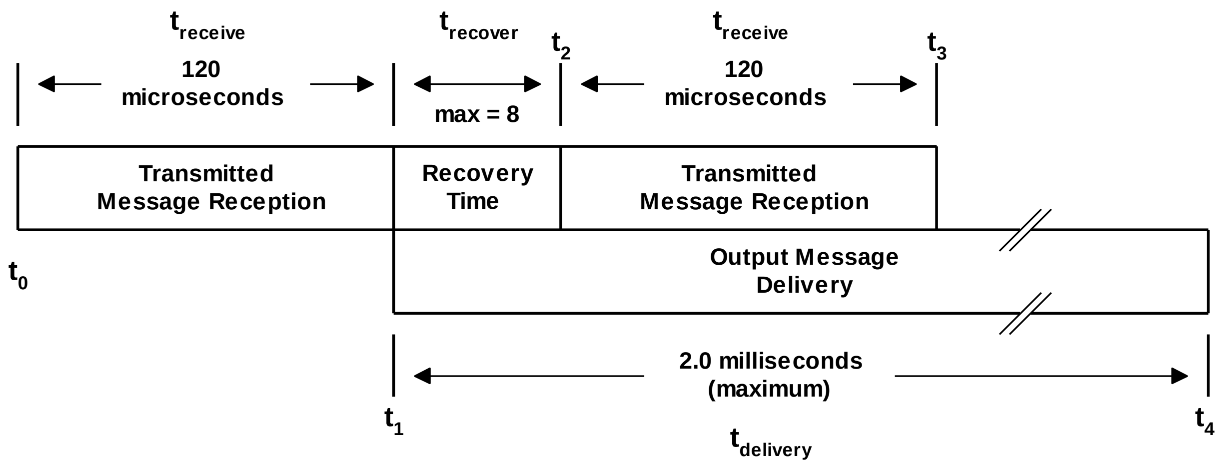


Figure 2-18: ADS-B and TIS-B Message Reception Function Output Message Delivery

The ADS-B and TIS-B Message Reception Function **shall** deliver All *OUTPUT MESSAGES* to the user interface or the Report Assembly function within 2.0 milliseconds of the receipt of the last message bit of the transmitted message.

2.2.7 ADS-B Message Processor Characteristics

2.2.7.1 ADS-B Receiving Device Message Reception

The ADS-B Receiver **shall** decode all valid ADS-B transmitted messages and structure the information from such messages into the appropriate ADS-B Reports identified in subsequent sections of this document. The structured reports **shall** then be made available to the appropriate user application as needed.

Future versions of these MOPS are expected to maintain backward compatibility with RTCA DO-260B. Messages originating from 1090 MHz ADS-B Transmitting Subsystems reporting a MOPS Version Number value that is indicated in Table 2-69 as "Reserved" are to be considered valid. However, all message types and all subfields within messages that are currently "Unassigned," or are indicated as being "Reserved" by these MOPS, **shall** be ignored and not used for ADS-B Report Generation.

2.2.7.1.1 Receipt of TYPE Code Equal to ZERO

An ADS-B Message containing a TYPE Code of ZERO (binary 0 0000) can only be used to update the altitude data of an aircraft that is already being tracked by the entity receiving the altitude data in a TYPE ZERO ADS-B Message.

If an ADS-B Message with TYPE Code equal to ZERO is received, it should be checked to see if altitude data is present and then process the altitude data as follows:

a. If altitude data is not present, the message **shall** be discarded.

b. If altitude data is present, it may be used to update altitude as needed.

Note: *For TCAS systems, this could be an aircraft that was being maintained via hybrid surveillance when the position data input failed. In this case, altitude only could be used for a short period of time. Interrogation would have to begin at the update rate for that track to ensure update of range and bearing information on the TCAS display.*

2.2.8 ADS-B Report Characteristics

The intent of the following subparagraphs is to provide an example coding of each type of ADS-B report. Implementations may use alternative report structures and coding of the ADS-B reports. However, the contents of each Report Type, as specified in Table 2-82 **shall** include, as a minimum, the data parameters as specified in the following subparagaphs.

Note: *This requirement describes the Report Type structure, not the contents of each report that can contain a subset of the complete allowed parameters.*

2.2.8.1 ADS-B State Vector Report Characteristics

Table 2-81 and the subsequent subparagraphs identify the data structure for all ADS-B State Vector Reports generated for each ADS-B vehicle being reported.

The Report Assembly Function **shall** be compatible with the current and prior versions of the relevant 1090 MHz ADS-B Messages (e.g., Airborne Position, Surface Position, Airborne Velocity) that are used as the basis for generating State Vector Reports. The relevant Version Two (2) messages are identified below and the relevant Version Zero (0) messages, conformant to RTCA DO-260, including Change 1, and Version One (1) messages, conformant to DO-260A including Change 1 and Change 2, and their required use for ADS-B State Vector Report generation are defined in Appendix N, Section N.3.

The intent of Table 2-81 is to illustrate the structure of all Items (i.e., parameters) required to be reported in an ADS-B State Vector Report. The exact structure of the data indicated in columns 10 and 11 is provided as a guideline or one possible method of satisfying the report structure. Implementers may choose to organize the data in another format; however, delivery to a user interface or application of all Items in Table 2-81 **shall** be consistent with the range, resolution, and units indicated in column 7, 8 and 9 of Table 2-81 respectively. If data is not available to support a field that is delivered to an application, then the data provided to the application **shall** be set to ALL ZEROs. Those requirements in §2.2.8.1.1 to §2.2.8.1.22 below that relate to specific data structure details (byte numbers, and bit numbers within the bytes) **shall** only apply to equipment that uses the sample report data structure shown in columns 10-11 of Table 2-81.

Note: *Table 2-81 is structured such that column 1, 2, and 6 through 11, pertain to the State Vector Report elements and how such elements should be structured into the report. Columns 3 through 5 provide information on where the appropriate data can be located in the ADS-B Messages for each of the Report elements.*

Table 2-81: ADS-B State Vector Data Elements - Source Data Mapping To Report Structure

Table 2-81: ADS-B State Vector Data Elements – Source Data Mapping To Report Structure											
Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	Parameter / Contents	Notes	Received Message Structure	"ME" Field Bits	Message Field Bits	# of Bits	Range	Resolution	Units	Data Structure	Data Byte #
0a, 0b	Report Type and Structure Identification	2	N/A	N/A	1 – 5	24	N/A	N/A	discrete	MddL Mddd dddddddd ddddddL	0 -2
0c	Validity Flags		N/A	N/A	N/A	16	N/A	N/A	discrete	dddddddd dddddddd	3 - 4
1	Participant Address		Airborne Position - "AA" Surface Position - "AA" Airborne Velocity – "AA"	N/A N/A N/A	9 - 32 9 – 32 9 - 32	24	N/A	N/A	discrete	Mddddddd dddddddd dddddddL	5 - 7
2	Address Qualifier		Aircraft ID & Category "Emitter Category" All Messages with DF=18 – "CF"	6 – 8 N/A	38 – 40 6 - 8	8	N/A	N/A	discrete	xxxxxMdL	8
3	Report Time of Applicability (Position and Velocity)	3	Airborne Position – "Time" Surface Position – "Time" Airborne Velocity	21 21 N/A	53 53 N/A	48	511.9921875	0.0078125 (1/128)	seconds	Mddddddd dddddddL Mddddddd dddddddL Mddddddd dddddddL	9 - 14
4	Encoded Latitude (WGS-84)		Airborne Position Surface Position –	23 - 39 23 - 39	55 - 71 55 – 71	24	± 180	0.0000215	degrees	SMddddddd dddddddd dddddddL	15 - 17
5	Encoded Longitude (WGS-84)		Airborne Position Surface Position	40 - 56 40 - 56	72 - 88 72 – 88	24	± 180	0.0000215	degrees	SMddddddd dddddddd dddddddL	18 - 20
6	Altitude, Geometric (WGS-84)	4	Airborne Position – "TYPE", & "Altitude" Airborne Velocity - "Diff. from Baro Alt sign" & "Diff. from Baro. Alt."	1 - 5, & 9 - 20 49 50 - 56	33 - 37 41 – 52 81 82 - 88	24	± 131072	0.015625	feet	SMddddddd dddddddd dddddddL	21 – 23
7	North/South Velocity	4	Airborne Velocity – "N/S Direction" & "N/S Velocity"	25 26 - 35	57 58 – 67	16	± 4096	0.125	knots	SMddddddd dddddddL	24 – 25
8	East/West Velocity	4	Airborne Velocity - "E/W Direction" & "E/W Velocity"	14 15 - 24	46 47 – 56	16	± 4096	0.125	knots	SMddddddd dddddddL	26 – 27
9	Ground Speed while on the Surface	5	Surface Position – "Movement"	6 - 12	38 – 44	8	N/A	N/A	discrete	MddddddL	28
10	Heading while on the Surface	5	Surface Position – "Heading"	14 - 20	46 – 52	8	± 180	1.40625	degrees	SMdddddL	29
11	Altitude, Barometric (Pressure Altitude)	4	Airborne Position – "TYPE", & "Altitude"	1 - 5 9 - 20	33 – 37 41 – 52	24	± 131072	0.015625	feet	SMddddddd dddddddd dddddddL	30 – 32
12	Vertical Rate, Geometric/Barometric (WGS-84)	4	Airborne Velocity – "Vert. Rate Source", "Vert. Rate Sign" &	36 37	68 69	16	± 32768	1.0	ft./min.	SMddddddd dddddddL	33 – 34

Table 2-81: ADS-B State Vector Data Elements – Source Data Mapping To Report Structure											
Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	Parameter / Contents	Notes	Received Message Structure	"ME" Field Bits	Message Field Bits	# of Bits	Range	Resolution	Units	Data Structure	Data Byte #
			"Vert. Rate"	38 - 46	70 – 78						
13	Navigation Integrity Category (NIC)		Airborne Position "Type Code" & NIC Supplement-B Operationsl Status - NIC Supplement-A Surface Position "Type Code" & Operational Status - NIC Supplement-A and NIC Supplement-C	1 – 5 8 44 1 – 5 44, 20	33 – 37 40 76 33 – 37 76, 52	8	N/A	N/A	discrete	xxxMdddL	35
14	Estimated Latitude (WGS-84)	6	Airborne Position – "Encoded Latitude" Surface Position – "Encoded Latitude"	23 – 39 23 - 39	55 – 71 55 – 71	24	± 180	0.0000215	degrees	SMddddddd dddddddd ddddddL	36 – 38
15	Estimated Longitude (WGS-84)	6	Airborne Position – "Encoded Longitude" Surface Position – "Encoded Longitude"	40 - 56 40 - 56	72 - 88 72 – 88	24	± 180	0.0000215	degrees	SMddddddd dddddddd ddddddL	39 – 41
16	Estimated North/South Velocity	6	Airborne Velocity – "N/S Direction" & "N/S Velocity"	25 26 - 35	57 58 – 67	16	± 4,096	0.125	knots	SMdddddd ddddddL	42 – 43
17	Estimated East/West Velocity	6	Airborne Velocity - "E/W Direction" & "E/W Velocity"	14 15 - 24	46 47 – 56	16	± 4,096	0.125	knots	SMdddddd ddddddL	44 – 45
18	Surveillance Status/Discretes		Airborne Position – "Surveillance Status" Airborne Velocity – "Intent Change Flag"	6 – 7 9	38 – 39 9	4 4	N/A	N/A	discrete	dddd dddd	46
19	Report Mode		N/A	N/A	N/A	8	N/A	N/A	discrete	xxxxxxML	47
										TOTAL BYTES	48

Notes:

1. *In the "Data Structure" column (i.e., column 10), "S" indicates the "sign-bit," "M" indicates the Most Significant Bit of the data field, "d" indicates data bits in the field, "L" indicates the Least Significant Bit of the data field, "0" indicates the bit is to always be set to a value of zero (0) and "x" indicates "Don't Care" bits in the data field.*
2. *The Report Type Identifier is used to identify the type of ADS-B Report being generated as specified in §2.2.8.1.1.1.*
3. *The Time of Applicability is actually a grouping of 3 individual parameters as specified in §2.2.8.1.4.*
4. *Parameters annotated with Note 4 are only present in the State Vector Report when the aircraft is airborne*

5. *Parameters annotated with Note 5 are only present in the State Vector Report with the aircraft is on the airport surface*
6. *Estimated values may be either an actual value from a received message, if available, or a calculated value such as produced by a surveillance tracker algorithm. For example it is possible for a surveillance tracker to produce an updated estimate of the target's horizontal position based on just the receipt of a new velocity message.*

2.2.8.1.1 State Vector Report Type and Structure Identification and Validity Flags

2.2.8.1.1.1 State Vector Report Type and Structure Identification

The Report Type is used to identify the type of ADS-B Report being generated by the report generation function and being provided to the User Application. The Report Type is a 4-bit field and **shall** be provided in the most significant nibble (i.e., bits 7 - 4) of the first byte (i.e., byte "0") of the Report. The Report Type formats and maximum number of bytes to be contained in each report are identified in Table 2-82.

Table 2-82: ADS-B Report Type Coding

Coding (binary)	Coding (decimal)	Report Type	Maximum Number of Bytes in Report
0000	0	Undefined Report Type or no Report Available	1
0001	1	State Vector Report for ALL Class "A" Equipment	48
0010	2	Mode-Status Report for Class "A1S," "A1," "A2," and "A3" Equipment	35
0011	3	Reserved for Version ONE (1) ADS-B Target State Report	22
0100	4	Air Reference Velocity Report for Class "A1S," "A1," "A2" and "A3" equipment	14
0101	5	ADS-B Target State and Status Report for Class "A2" and "A3" Equipment (Optional for Equipment Classes "A1S and A1").	22
0110	6	Reserved for Trajectory Change Report for Class "A2" and "A3" equipment	
0111 through 1111		Not Assigned (Reserved for Future Assignment)	

The Report Structure field is used to indicate the exact data parameters identified in Table 2-81 that are being provided in the State Vector report and is intended to provide a methodology for the report processor to structure shorter reports when data for some parameters or groups of related parameters are not available. In order to provide the capability to provide shorter State Vector reports the following basic conventions **shall** be adhered to:

a. Any given data parameter to be used in the report **shall** use the designated number of bytes and format as designated in Table 2-81.

b. Whenever a data parameter identified in Table 2-81, or a required grouping of data parameters as identified in Table 2-83, is not provided in the report, then it is permissible to concatenate the next parameter to be included into the report immediately following the inclusion of the previous reported parameter. This feature **shall** be used accommodate the reporting of the different sets of required parameters, such as for when the aircraft is in the airborne condition versus on the airport surface as indicated in Table 2-81.

c. Each parameter of the State Vector report identified in Table 2-81 **shall** be properly declared in the Report Structure field as detailed in the following paragraphs and Table 2-83.

Note: *Implementation of the methodology just provided is realizable and controllable due to the fact that the exact length of each report parameter is specified in Table 2-81 and the Report Structure field identifies exactly which parameters are included in the report. Therefore, the report user can easily re-construct the length and general format of the report.*

The Report Structure is a 20-bit field and **shall** be provided in the least significant nibble (i.e., bits 3 - 0) of the first byte (i.e., byte "0") and continuing into bytes 1 and 2 of the Report. The Report Structure format is specified in Table 2-83 where each bit is associated with a particular data parameter, or group of data parameters, of the State Vector Report. If the bit is set to ONE (1), then the data parameter, or group of identified data parameters, is considered to be available and **shall** be transmitted in the report. Otherwise, the data parameter, or group of identified data parameters, is considered to not be available and **shall** not be transmitted in the report. Note that Table 2-83 does not address the Report Type and Structure Identification parameter, the Validity Flags parameter, nor the Participant Address parameter and the Address Qualifier, **since these four parameters shall be included in the State Vector Report. Also, certain of the other State Vector data parameters are required to be reported, as specified in §2.2.9, even though bits have been allocated in the report structure field as shown in Table 2-83.**

Table 2-83: ADS-B State Vector Report Structure Coding

Byte #	Bit #	State Vector Data Parameter(s) to be Reported	Number of Bytes
0	3	Time of Applicability for Estimated Position/Velocity	2
	2	Position Time of Applicability	2
	1	Velocity Time of Applicability	2
	0	Latitude (WGS-84) & Longitude (WGS-84)	7
1	7	Altitude, Geometric (WGS-84)	4
	6	North/South Velocity & East/West Velocity	5
	5	Ground Speed while on the Surface	2
	4	Heading while on the Surface	2
	3	Altimeter, Barometric	4
	2	Vertical Rate Geometric/Baro.	3
	1	Navigation Integrity Category	1
	0	Estimated Latitude	3
2	7	Estimated Longitude	3
	6	Estimated North/South Velocity	2
	5	Estimated East/West Velocity	2
	4	Surveillance Status/Discretes	1
	3	Report Mode	1
	2	Reserved for Future Expansion	
	1	Reserved for Future Expansion	
	0	Reserved for Future Expansion	

2.2.8.1.1.2 State Vector Report Validity Flags

Validity Flags for data provided in the State Vector Report **shall** be indicated in bytes #3 and #4 of the State Vector Report as shown for item "0c" in Table 2-81. The State Vector Report elements that require validity flags are identified in Table 2-84. Table 2-84 identifies the byte and bit that **shall** be used as a flag for each element that requires a validity flag. Each validity flag bit **shall** be set to ONE (1) to indicate that the corresponding State Vector Report Element data is valid. If such data is not valid, then the corresponding validity flag bit **shall** be set to ZERO (0).

Table 2-84: ADS-B State Vector Report Validity Flag Requirements

SV Report Item #	State Vector Report Element	Validity Flag Bit Required?	Validity Flag Bit Assignment	
			Byte #	**Bit #**
0a	Report Type	No		
0b	Structure Identification	No		
0c	Validity Flags	No		
1	Participant Address	No		
2	Address Qualifier	No		
3	Report Time of Applicability	No		
4	Latitude (WGS-84)	**Yes** (This validity flag bit is for Horizontal Position Valid)	3	7 (MSB)
5	Longitude (WGS-84)	**Yes** (This validity flag bit is for Horizontal Position Valid)	3	7
6	Altitude, Geometric (WGS-84)	**Yes** (This bit is validity flag bit for Geometric Altitude Valid)	3	6
7	North/South Velocity	**Yes** (This bit is validity flag bit for Airborne Horizontal Velocity Valid)	3	5
8	East/West Velocity	**Yes** (This bit is validity flag bit for Airborne Horizontal Velocity Valid)	3	5
9	Ground Speed while on the Surface	**Yes** (This bit is validity flag bit for Surface Ground Speed Valid)	3	4
10	Heading while on the Surface	**Yes** (This bit is validity flag bit for Surface HeadingValid)	3	3
11	Altitude, Barometric (Pressure Altitude)	**Yes** (This bit is validity flag bit for Barometric Altitude Valid)	3	2
12a	Vertical Rate, Geometric (WGS-84)	**Yes** (This bit is validity flag bit for Geometric Vertical Rate Valid)	3	1
12b	Vertical Rate, Barometric (WGS-84)	**Yes** (This bit is validity flag bit for Barometric Vertical Rate Valid)	3	0
13	Navigation Integrity Category (NIC)	No		
14	Estimated Latitude (WGS-84)	**Yes** (This validity flag bit is for Estimated Horizontal Position Valid -- If for some reason an estimation cannot be made of the horizontal position at the TOA of the report, then this could be indicated by zeroing the validity flag for the estimated horizontal position.)	4	7 (MSB)
15	Estimated Longitude (WGS-84)	**Yes** (This validity flag bit is for Estimated Horizontal Position Valid -- If for some reason an estimation cannot be made of the horizontal position at the TOA of the report, then this could be indicated by zeroing the validity flag for the estimated horizontal position.)	4	7
16	Estimated North/South Velocity	**Yes** (This validity flag bit is for Estimated Horizontal Velocity Valid -- It may be possible to estimate velocity at some time after the TOA of the velocity message.)	4	6
17	Estimated East/West Velocity	**Yes** (This validity flag bit is for Estimated Horizontal Velocity Valid -- It may be possible to estimate velocity at some time after the TOA of the velocity message.)	4	6
18	Surveillance Status/Discretes	No		
19	Report Mode	No		

2.2.8.1.2 Participant Address

The Participant Address **shall** be encoded as specified in §2.2.3.2.1.5.

2.2.8.1.3 Address Qualifier

The Address Qualifier is used to indicate the type of Participant Address (§2.2.3.2.1.5) being reported. The 3 least significant bits of the one byte field (byte 8 of the Report Field) are used to convey the Address Qualifier information. The Address Qualifier subfield **shall** be coded as shown in Table 2-85.

<u>Table 2-85:</u> Address Qualifier Coding

Coding (MdL)	**Meaning**	**ADS-B Emitter Cateogry Set** (see Notes 1 & 2)
000	ICAO address being reported as Participant Address for an unknown emitter category	See Note 3
001	Non-ICAO address being reported as Participant Address for an unknown emitter category	See Note 3
010	ICAO address being reported as Participant Address for an Aircraft	"A" or "B"
011	Non-ICAO address being reported as Participant Address for an Aircraft	"A" or "B"
100	ICAO address being reported as Participant Address is for a Surface Vehicle, a Fixed Ground or Tethered Obstruction	"C"
101	Non-ICAO address being reported as Participant Address is for a Surface Vehicle, a Fixed Ground or Tethered Obstruction	"C"
110	Reserved	N/A
111	Reserved	N/A

<u>Notes for Table 2-85:</u>

1. *All transponder-based based 1090 MHz ADS-B systems are required to use an ICAO 24-bit address. Certain types of non-transponder-based 1090 MHz ADS-B systems may under certain conditions be permitted to broadcast an address other than an ICAO 24-bit address. ADS-B Messages received from Non-Transponder Devices transmitting with DF=18 and CF=1 indicate that a non-ICAO Address is being used (see Figure 2-2).*
2. *The Emitter Category associated with the Participant Address is to be obtained from the "ADS-B Emitter Category" subfield (§2.2.3.2.5.2) of the ADS-B Aircraft Identification and Category Message.*
3. *An Address Qualifier Code of 000 or 001 is to be reported if the value from the "ADS-B Emitter Category" subfield indicates "No ADS-B Emitter Category Information," or if an ADS-B Aircraft Identification and Category Message has not been received.*

2.2.8.1.4 Report Time of Applicability

Since separate messages are used for position and velocity, the Time of Applicability is reported individually for the position related report parameters and the velocity related report parameters. Also the State Vector Report may include estimated position and/or velocity values (i.e., not based on the receipt of a message with updated position or velocity information). In this latter case the State Vector report **shall** include a Time of

Applicability for the estimated position/velocity parameters. The six-byte Report Time of Applicability Parameter field, as specified in Table 2-81, is sub-divided into three subfields as shown in Table 2-86. The coding of the subfields is specified in the following subparagraphs.

Table 2-86: Report Time of Applicability Parameter Coding

Subfield	Coding
Time of Applicability for Estimated Position/Velocity	Mddddddd dddddddL
Position Time of Applicablity	Mddddddd dddddddL
Velocity Time of Applicabilty	Mddddddd dddddddL

Note: *In the "Coding" column, "M" indicates the Most Significant Bit of the data field and "L" indicates the Least Significant Bit of the data field.*

2.2.8.1.4.1 Time of Applicability for Estimated Position/Velocity

The Time of Applicability for the estimated position and velocity **shall** be generated under the conditions specified below:

a. Each time that an individual State Vector Report is updated as specified in §2.2.8.1.17, §2.2.8.1.18, §2.2.8.1.19, ***OR*** §2.2.8.1.20, the Report Assembly Function **shall** update the Time of Applicability for the Estimate Position/Velocity data in the State Vector Report with either the GPS/GNSS UTC Measure Time data (§2.2.8.5.1) or the Established Receiver Unit Time (§2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

b. Time of Applicability data **shall** be provided in the State Vector report in binary format as specified in Table 2-86**.**

2.2.8.1.4.2 Position Time of Applicability

Processing of Position Time of Applicability depends on the UTC Time of Message Receipt of the Position Message and the value of the "TIME" (T) bit in the Position Message.

2.2.8.1.4.2.1 Position Time of Applicability when "TIME" (T)=0

Each time that an Airborne or Surface Position Message is received with valid Latitude ***AND*** Longitude data and "TIME" (T)=0, the Report Assembly Function **shall** update the Position Time of Applicability data in the State Vector Report with the Time of Message Receipt of the Position Message expressed as either GPS/GNSS UTC Measure Time data (see §2.2.8.5.1), or the Established Receiver Unit Time (see §2.2.8.5.2). Time of Applicability shall be rounded to the nearest LSB of the Position Time of Applicability field.

2.2.8.1.4.2.2 Position Time of Applicability when "TIME" (T)=1 and UTC Time of Message Receipt is Available

Each time that an Airborne or Surface Position Message is received with "TIME" (T)="1" and valid Latitude ***AND*** Longitude data, and when a valid UTC Time of

Message Receipt is available per §2.2.8.5.1, the Report Assembly Function **shall** update the Position Time of Applicability data in the State Vector Report with the appropriate 0.2 second UTC epoch. The appropriate 0.2 second UTC epoch is determined as follows:

- If "CPR Format" (F)=0, Position Time of Applicability **shall** be the nearest even 0.2 second UTC epoch to the time that the Airborne Position Message is received, expressed as GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) and rounded to the nearest LSB of the Position Time of Applicability field.

- If "CPR Format" (F)=1, Position Time of Applicability **shall** be the nearest odd 0.2 second UTC epoch to the time that the Airborne Position Message is received, expressed as GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) and rounded to the nearest LSB of the Position Time of Applicability field.

Note: *An "even 0.2 second UTC epoch" is defined as that moment on the UTC time that occurs at an even number of 200-millisecond intervals after an exact even-numbered UTC second. Likewise, an "odd 0.2 second UTC epoch" is defined as that moment on the UTC time scale that occurs at an odd number of 200 millisecond intervals after an even numbered UTC second. Examples of even 0.2 second epochs are 12.0 seconds, 12.4 seconds, 12.8 seconds, 13.2 seconds, 13.6 seconds, etc. Examples of odd 0.2 second epochs are 12.2 seconds, 12.6 seconds, 13.0 seconds, 13.4 seconds, 13.8 seconds, etc.*

2.2.8.1.4.2.3 Position Time of Applicability when "TIME" (T)=1 and UTC Time of Message Receipt is NOT Available

Each time that an Airborne or Surface Position Message is received with "TIME" (T)=1 and valid Latitude ***AND*** Longitude data, and when no valid UTC Time of Message Receipt per §2.2.8.5.1 is available, the Position Time of Applicability **shall** be processed as specified in §2.2.8.1.4.2.1.

2.2.8.1.4.3 Velocity Time of Applicability

Each time that an Airborne Velocity Message - Subtype=1 or "2" is received with valid East/West AND North/South Velocity data, the Report Assembly Function **shall** update the Velocity Time of Applicability data in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Each time that a Surface Position Message is received with valid Movement AND Ground Track data, the Report Assembly Function **shall** update the Velocity Time of Applicability data in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

2.2.8.1.5 Latitude (WGS-84)

The ADS-B Report Assembly Function **shall** decode the Encoded Latitude data (§2.2.3.2.3.7 and /or §2.2.3.2.4.7) provided in the ADS-B broadcast. Decoding of the encoded latitude data **shall** be performed in accordance with §A.1.7.4 through §A.1.7.8.2 of Appendix A. Latitude data **shall** be provided to the user application in the State Vector report in angular weighted binary format (M bit = 90 degrees, S bit = negative, or 180 degrees) as specified in Table 2-81.

When valid encoded latitude data is not available, the latitude data provided to the user application **shall** be set to ALL ZEROs, and the Horizontal Position Validity Flag bit, i.e., bit #7 (MSB) of byte #3 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Horizontal Position data is not valid. Otherwise, the Horizontal Position Validity Flag bit, i.e., bit #7 (MSB) of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.6 Longitude (WGS-84)

The ADS-B Report Assembly Function **shall** decode the Encoded Longitude data (§2.2.3.2.3.8 and / or 2.2.3.2.4.8) provided in the ADS-B broadcast. Decoding of the encoded longitude data **shall** be performed in accordance with §A.1.7.4 through A.1.7.8.2 of Appendix A. Latitude data **shall** be provided to the user application in the State Vector report in angular weighted binary format (M bit = 90 degrees, S bit = negative, or 180 degrees) as specified in Table 2-81.

When valid encoded longitude data is not available, the longitude data provided to the user application **shall** be set to ALL ZEROs, and the Horizontal Position Validity Flag bit, i.e., bit #7 (MSB) of byte #3 of the State Vector Report, **shall** be set to ZERO (0) to indicate that the reported Horizontal Position data is not valid. Otherwise, the Horizontal Position Validity Flag bit, i.e., bit #7 (MSB) of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.7 Altitude, Geometric (WGS-84)

a. When Geometric Altitude Data is indicated by the “TYPE” subfield (§2.2.3.2.3.1) the ADS-B Report Assembly Function **shall** decode Altitude Data (§2.2.3.2.3.4) that has been encoded by the ADS-B Transmitting Subsystem as specified in §2.2.3.2.3.4.2.

b. Alternatively, Barometric Altitude Data (§2.2.3.2.3.4.1), Difference from Barometric Altitude Sign Bit (§2.2.3.2.6.1.14, §2.2.3.2.6.2.14, §2.2.3.2.6.3.14 or §2.2.3.2.6.4.14), and Difference from Barometric Altitude (§2.2.3.2.6.1.15, §2.2.3.2.6.2.15, §2.2.3.2.6.3.15 or §2.2.3.2.6.4.15), **shall** be decoded and the Geometric Altitude computed by the receiver Report Assembly Function.

c. Geometric Binary Altitude data **shall** be provided to the user application in the State Vector report in binary format as specified in Table 2-81. This format represents a true two’s complement format where the MSB has a weight of 65,536 and the LSB has a weight of 0.015625. The maximum range of the data is then given by ±[2*MSB - LSB] or ±131071.984375.

d. When valid Geometric Altitude data is not available, the ADS-B receiver **shall** set the Geometric Altitude data provided to the user interface to ALL ZEROs, and the Geometric Altitude Validity Flag bit, i.e., bit #6 of byte #3 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Geometric Altitude is not valid. Otherwise, the Geometric Altitude Validity Flag bit, i.e., bit #6 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

Note: *Geometric Altitude is not required to be estimated when a State Vector Report is prepared as a result of receiving an airborne position and velocity messages. (i.e. The State Vector Report can include the most recently received value for this field.)*

2.2.8.1.8 North/South Velocity

a. The ADS-B Report Assembly Function **shall** extract the North/South Direction Bit (§2.2.3.2.6.1.8 or §2.2.3.2.6.2.8) and the North/South Velocity subfield (§2.2.3.2.6.1.9 or §2.2.3.2.6.2.9) from the ADS-B Message and provide North/South Velocity information to the user Application in the State Vector report in binary format as specified in Table 2-81. This format represents a true two's complement format where the MSB has a weight of 2,048 and the LSB has a weight of 0.125. The maximum range of the data is then given by ± [2*MSB - LSB] or ±4,095.875.

b. When valid North/South Velocity data is not available, the North/South Velocity data provided to the user application **shall** be set to ALL ZEROs, and the Airborne Horizontal Velocity Validity Flag bit, i.e., bit #5 of byte #3 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Airborne Horizontal Velocity is not valid. Otherwise, the Airborne Horizontal Velocity Validity Flag bit, i.e., bit #5 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.9 East/West Velocity

a. The ADS-B Report Assembly Function **shall** extract the East/West Direction Bit (§2.2.3.2.6.1.6 or §2.2.3.2.6.2.6) and the East/West Velocity subfield (§2.2.3.2.6.1.7 or §2.2.3.2.6.2.7) from the ADS-B Message and provide East/West Velocity information to the user application in the State Vector report in binary format as specified in Table 2-81. This format represents a true two's complement format where the MSB has a weight of 2,048 and the LSB has a weight of 0.125. The maximum range of the data is then given by ±[2*MSB - LSB] or ±4,095.875.

b. When valid East/West Velocity data is not available, the East/West Velocity data provided to the user application **shall** be set to ALL ZEROs, and the Airborne Horizontal Velocity Validity Flag bit, i.e., bit # 5 of byte #3 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indocate that the reported Airborne Horizontal Velocity is not valid. Otherwise, the Airborne Horizontal Velocity Validity Flag bit, i.e., bit #5 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.10 Ground Speed While on the Surface

a. The ADS-B Report Assembly Function **shall** extract the Movement Data (§2.2.3.2.4.2) from the ADS-B Surface Position Message and provide Ground Speed information to the user application in the State Vector report as specified in Table 2-81. Coding of the Movement information **shall** be the same as that identified for the Movement Data in §2.2.3.2.4.2.

b. When valid Movement data is not available, the ADS-B Report Assembly Function **shall** set the Ground Speed data provided to the user application to ALL ZEROs, and the Surface Ground Speed Validity Flag bit, i.e., bit #4 (LSB) of byte #3 of the State Vector Report, **shall** be set to ZERO (0) to indicate that the reported Surface Ground Speed is not valid. Otherwise, the Surface Ground Speed Validity Flag bit, i.e., bit #4 (LSB) of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.11 Heading While on the Surface

a. The ADS-B Report Assembly Function **shall** extract the Status Bit for Heading (§2.2.3.2.4.3) and Heading Data (§2.2.3.2.4.4) from the ADS-B Surface Position Message and provide Heading while on the surface information to the user application in the State Vector Report in binary format as specified in Table 2-81. This format represents a true two's complement format where the MSB has a weight of 90 degrees and the LSB has a weight of 1.40625 degrees. The maximum range of the data is then given by ±[2*MSB - LSB] or ±178.59375 degrees. Alternately, the format may be referred to as angular weighted binary.

b. When valid Heading while on the surface data is not available, the ADS-B Report Assembly Function **shall** set the Heading while on the surface data provided to the user application to ALL ZEROs, and the Surface Heading Validity Flag bit, i.e., bit #3 (MSB) of byte #3 of the State Vector Report, **shall** be set to ZERO (0) to indicate that the reported Surface Heading is not valid. Otherwise, the Surface Heading Validity Flag bit, i.e., bit #3 (MSB) of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.12 Altitude, Barometric (Pressure Altitude)

a. When Barometric Altitude Data is indicated by the "TYPE" subfield (§2.2.3.2.3.1) of the ADS-B Airborne Position Message, the ADS-B Report Assembly Function **shall** decode Altitude Data (§2.2.3.2.3.4) that has been encoded by the ADS-B Transmitting Subsystem as specified in §2.2.3.2.3.4.1. Binary Altitude data **shall** be provided to the user application in the State Vector report as specified in Table 2-81. This format represents a true two's complement format where the MSB has a weight of 65,536 and the LSB has a weight of 0.015625. The maximum range of the data is then given by ± [2*MSB - LSB] or ±131071.984375.

b. When valid Barometric Altitude data is not available, the ADS-B Report Assembly Function **shall** set the Barometric Altitude data provided to the user application to ALL ZEROs, and the Barometric Altitude Validity Flag bit, i.e., bit #2 of byte #3 of the State Vector Report, **shall** be set to ZERO (0) to indicate that the reported Barometric Altitude is not valid. Otherwise, the Barometric Altitude Validity Flag bit, i.e., bit #2 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

Note: *Barometric Altitude is not required to be estimated when a State Vector Report is prepared as a result of receiving an airborne position and velocity messages. (i.e. The State Vector Report can include the most recently received value for this field.)*

2.2.8.1.13 Vertical Rate, Geometric/Barometric

The "Vertical Rate" field in the State Vector Report contains the altitude rate of an airborne ADS-B Participant. This **shall** be either the rate of change of pressure altitude, or of geometric altitude, as specified by the "Vertical Rate Type" element in the Mode Status Report (§2.2.8.2.18).

2.2.8.1.14 Vertical Rate, Geometric (WGS-84)

a. When Geometric Altitude Rate Data is indicated by the "Source Bit for Vertical Rate" subfield (§2.2.3.2.6.1.10, §2.2.3.2.6.2.10, §2.2.3.2.6.3.10 or §2.2.3.2.6.4.10) the ADS-B Report Assembly Function **shall** extract the "Sign Bit for Vertical Rate" subfield (§2.2.3.2.6.1.11, §2.2.3.2.6.2.11, §2.2.3.2.6.3.11 or §2.2.3.2.6.4.11) and the "Vertical Rate" subfield (§2.2.3.2.6.1.12, §2.2.3.2.6.2.12, §2.2.3.2.6.3.12 or §2.2.3.2.6.4.12) from the ADS-B Message and provide Vertical Rate, Geometric information to the user application in the State Vector report in binary format as specified in Table 2-81. This format represents a true two's complement format where the MSB has a weight of 16,384 and the LSB has a weight of 1. The maximum range of the data is then given by ±[2*MSB - LSB] or ±32,767.

b. When valid Geometric Altitude Rate data is **not** available, the ADS-B Report Assembly Function **shall** set the Vertical Rate, Geometric data provided to the user application to ALL ZEROs, and the Geometric Vertical Rate Validity Flag bit, i.e., bit #1 of byte #3 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Geometric Vertical Rate is not valid. Otherwise, the Geometric Vertical Rate Validity Flag bit, i.e., bit #1 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

Note: *Geometric Altitude Rate is not required to be estimated when a State Vector Report is prepared as a result of receiving an airborne position and velocity messages. (i.e. The State Vector Report can include the most recently received value for this field.)*

2.2.8.1.15 Barometric Altitude Rate

a. When Barometric Altitude Rate Data is indicated by the "Source Bit for Vertical Rate" subfield (§2.2.3.2.6.1.10, §2.2.3.2.6.2.10, §2.2.3.2.6.3.10 or §2.2.3.2.6.4.10) the ADS-B Report Assembly Function **shall** extract the "Sign Bit for Vertical Rate" subfield (§2.2.3.2.6.1.11, §2.2.3.2.6.2.11, §2.2.3.2.6.3.11 or §2.2.3.2.6.4.11) and the "Vertical Rate" subfield (§2.2.3.2.6.1.12, §2.2.3.2.6.2.12, §2.2.3.2.6.3.12 or §2.2.3.2.6.4.12) from the ADS-B Message and provide Vertical Rate, Barometric information to the user application in the State Vector report in binary format as specified in Table 2-81. This format represents a true two's complement format where the MSB has a weight of 16,384 and the LSB has a weight of 1. The maximum range of the data is then given by ±[2*MSB - LSB] or ±32,767.

b. When valid Barometric Altitude Rate data is **not** available, the ADS-B Report Assembly Function **shall** set the Vertical Rate, Barometric data provided to the user application to ALL ZEROs, and the Barometric Vertical Rate Validity Flag bit, i.e., bit #0 of byte #3 of the State Vector Report, **shall** be set to ZERO (0). Otherwise, the Barometric Vertical Rate Validity Flag bit, i.e., bit #0 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

Note: *Barometric Altitude Rate is not required to be estimated when a State Vector Report is prepared as a result of receiving an airborne position and velocity messages. (i.e. The State Vector Report can include the most recently received value for this field.)*

2.2.8.1.16 Navigation Integrity Category (NIC)

The ADS-B Report Assembly Function **shall** provide Navigation Integrity Category (NIC) information in the State Vector Report. The NIC is derived from the "TYPE" Code data (§2.2.3.2.3.1) and the NIC Supplement-B value (§2.2.3.2.3.3) from the ADS-B Airborne Position Message, and the NIC Supplement-A value (§2.2.3.2.7.2.6) from the ADS-B Aircraft Operational Status Message, OR the "TYPE" Code data (§2.2.3.2.4.1) from the ADS-B Surface Position Message, and the NIC Supplement-A value (§2.2.3.2.7.2.6) and the NIC Supplement-C value (§2.2.3.2.7.2.3.11) from the ADS-B Aircraft Operational Status Message. The NIC values are encoded according to the NIC values given in Table 2-70, except for R_C < 0.3 NM which is encoded in the State Vector Report with a value of 6 in bits 0 to 3 in byte 35, with bit 4 in byte 35 set to ONE (1) (i.e., xxx10110). The NIC parameter is provided to the user application in the State Vector Report as specified in Table 2-81.

Note: *For backward compatability, applications designed to interface to the State Vector Report structure of RTCA DO-260A will decode R_C < 0.3 NM as NIC=6 and interpret it as R_C < 0.6 NM. Applications designed to comply with these MOPS will properly decode the NIC as R_C < 0.3 NM.*

2.2.8.1.17 Estimated Latitude (WGS-84)

a. New Latitude Data Received

(1). Airborne or Surface Message Received: - Each time that the Report Assembly Function establishes a new decoded Latitude in accordance with §2.2.8.1.2, the Report Assembly Function **shall** update the Estimated Latitude (WGS-84) data in the State Vector Report with the new Latitude data received.

(2). Airborne or Surface Message Received: - The Estimated Latitude update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

b. New North/South Velocity Data Received: (Airborne Velocity Message Received)

(1). Each time that an Airborne Velocity Message - Subtype=1 or "2" is received with valid North/South Velocity data, the Report Assembly Function **shall** compute a new Estimated Latitude (WGS-84) position based on the last known

Estimated Latitude (WGS-84), the last known North/South Velocity (***Note:*** Not the North/South Velocity data just received), and the time that has elapsed since the last update of the Estimated Latitude (WGS-84).

Accuracy of the Estimated Latitude (WGS-84) computation **shall** be within ±20 meters of the theoretical noise free position that could be established based on the previous position, the last known velocity, and the time of travel.

Note: *The accuracy requirement is stated in the manner given in order to specifically allow the implementation to use estimation techniques such as Kalman filters, alpha-beta trackers, or linear estimation as deemed necessary by the implementer to satisfy the accuracy requirement.*

(2). The new Estimated Latitude (WGS-84) computed in b.(1) **shall** be used by the Report Assembly Function to update the Estimated Latitude (WGS-84) data in the State Vector Report.

(3). The Estimated Latitude update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

c. Estimated Horizontal Position Validity Flag Requirements

When valid estimated Latitude or Longitude position data is not available, the estimated latitude and longitude data provided to the user application **shall** be set to ALL ZEROs and the Estimated Horizontal Position Validity Flag bit, i.e., bit #7 of byte #4 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Estimated Horizontal Position is not valid.

Otherwise, the Estimated Horizontal Position Validity Flag bit, i.e., bit #7 of byte #4 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.18 Estimated Longitude (WGS-84)

a. New Longitude Data Received

(1). Airborne or Surface Message Received: - Each time that the Report Assembly Function establishes a new decoded Longitude in accordance with §2.2.8.1.6, the Report Assembly Function **shall** update the Estimated Longitude (WGS-84) data in the State Vector Report with the new Longitude data received.

(2). Airborne or Surface Message Received: - The Estimated Longitude update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

b. New East/West Velocity Data Received: (Airborne Velocity Message Received)

(1). Each time that an Airborne Velocity Message - Subtype=1 or “2” is received with valid East/West Velocity data, the Report Assembly Function **shall** compute a new Estimated Longitude (WGS-84) position based on the last known

Estimated Longitude (WGS-84), the last known East/West Velocity (***Note:*** Not the East/West Velocity data just received), and the time that has elapsed since the last update of the Estimated Longitude (WGS-84).

Accuracy of the Estimated Longitude (WGS-84) computation **shall** be within ±20 meters of the theoretical noise free position that could be established based on the previous position, the last known velocity, and the time of travel.

Note: *The accuracy requirement is stated in the manner given in order to specifically allow the implementation to use estimation techniques such as Kalman filters, alpha-beta trackers, or linear estimation as deemed necessary by the implementer to satisfy the accuracy requirement.*

(2). The new Estimated Longitude (WGS-84) computed in b.(1) **shall** be used by the Report Assembly Function to update the Estimated Longitude (WGS-84) data in the State Vector Report.

(3). The Estimated Longitude update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

c. Estimated Horizontal Position Validity Flag Requirements

When valid estimated Latitude or Longitude position data is not available, the estimated latitude and longitude data provided to the user application **shall** be set to ALL ZEROs and the Estimated Horizontal Position Validity Flag bit, i.e., bit #0 of byte #3 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Estimated Horizontal Position is not valid.

Otherwise, the Estimated Horizontal Position Validity Flag bit, i.e., bit #0 of byte #3 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.19 Estimated North/South Velocity

Note: *The estimation of North/South Velocity is considered to be an optional function to be implemented in the ADS-B Report Assembly Function at the discretion of the implementer. If estimation of North/South Velocity is implemented then the requirements provided in the following subparagraphs a. through b.(3) are to be used as the minimum acceptable performance for such estimation.*

a. New North/South Velocity Received: (Airborne Velocity or Surface Position Message Received)

(1). Each time that the Report Assembly Function establishes a new North/South Velocity in accordance with §2.2.8.1.8, the Report Assembly Function **shall** update the Estimated North/South Velocity data in the State Vector Report with the new North/South Velocity data received.

(2). The Estimated North/South Velocity update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

b. New Latitude Position Data Received: (Airborne Position or Surface Position Message Received)

(1). Each time that the Report Assembly Function establishes a new decoded Latitude in accordance with §2.2.8.1.2, the Report Assembly Function **shall** compute a new Estimated North/South Velocity based on the last known Estimated Latitude (WGS-84), the new Latitude position data just received, and the time that has elapsed since the last update of the Estimated North/South Velocity.

Accuracy of the Estimated North/South Velocity computation **shall** be within ±0.3 meters/second of the theoretical noise free Estimated North/South Velocity that could be established based on the previous position, the new position, and the elapsed time of travel between the two positions.

Note: *The accuracy requirement is stated in the manner given in order to specifically allow the implementation to use estimation techniques such as Kalman filters, alpha-beta trackers, or linear estimation as deemed necessary by the implementer to satisfy the accuracy requirement.*

(2). The new Estimated North/South Velocity computed in b.(1) **shall** be used by the Report Assembly Function to update the Estimated North/South Velocity data in the State Vector Report.

(3). The Estimated North/South Velocity update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

c. Estimated Velocity Validity Flag Requirements

When valid estimated North/South or East/West Velocity data is not available, the estimated North/South or East/West Velocity data provided to the user application **shall** be set to ALL ZEROs and the Estimated Horizontal Velocity Validity Flag bit, i.e., bit #6 of byte #4 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Estimated Horzontal Velocity is not valid.

Otherwise, the Estimated Horizontal Velocity Validity Flag bit, i.e., bit #6 of byte #4 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.20 Estimated East/West Velocity

Note: *The estimation of East/West Velocity is considered to be an optional function to be implemented in the ADS-B Report Assembly Function at the discretion of the implementer. If estimation of East/West Velocity is implemented then the requirements provided in the following subparagraphs a. through b.(3) are to be used as the minimum acceptable performance for such estimation.*

a. <u>New East/West Velocity Data Received:</u> (Airborne Velocity or Surface Position Message Received)

(1). Each time that the Report Assembly Function establishes a new East/West Velocity in accordance with §2.2.8.1.9, the Report Assembly Function **shall** update the Estimated East/West Velocity data in the State Vector Report with the new East/West Velocity data received.

(2). The Estimated East/West Velocity update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

b. <u>New Longitude Position Data Received:</u> (Airborne or Surface Position Message Received)

(1). Each time that the Report Assembly Function establishes a new decoded Longitude in accordance with §2.2.8.1.6, the Report Assembly Function **shall** compute a new Estimated East/West Velocity based on the last known Estimated Longitude (WGS-84), the new Longitude position data just received, and the time that has elapsed since the last update of the Estimated East/West Velocity.

Accuracy of the Estimated East/West Velocity computation **shall** be within ±0.3 meters/second of the theoretical noise free Estimated East/West Velocity that could be established based on the previous position, the new position, and the elapsed time of travel between the two positions.

Note: *The accuracy requirement is stated in the manner given in order to specifically allow the implementation to use estimation techniques such as Kalman filters, alpha-beta trackers, or linear estimation as deemed necessary by the implementer to satisfy the accuracy requirement.*

(2). The new Estimated East/West Velocity computed in b.(1) **Shall** be used by the Report Assembly Function to update the Estimated East/West Velocity data in the State Vector Report.

(3). The Estimated East/West Velocity update **shall** be completed by the Report Assembly Function also updating the Report Time of Applicability in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2) whichever is applicable to the Receiving device Report Assembly Function installation requirements.

c. Estimated Horizontal Velocity Validity Flag Requirements

When valid estimated North/South or East/West Velocity data is not available, the estimated North/South or East/West Velocity data provided to the user application **shall** be set to ALL ZEROs and the Estimated Horizontal Velocity Validity Flag bit, i.e., bit #7 of byte #4 of the State Vector Report (§2.2.8.1.1.2), **shall** be set to ZERO (0) to indicate that the reported Estimated Horzontal Velocity is not valid.

Otherwise, the Estimated Horizontal Velocity Validity Flag bit, i.e., bit #7 of byte #4 of the State Vector Report, **shall** be set to ONE (1), unless modified by other conditions.

2.2.8.1.21 Surveillance Status / Discretes

a. The ADS-B Report Assembly Function **shall** extract the Surveillance Status (§2.2.3.2.3.2) from the ADS-B Airborne Position Message (§2.2.3.2.3) and map the surveillance status data into the most significant nibble of the State Vector Report byte on a bit for bit basis as shown in Table 2-81.

b. When valid Surveillance Status data is not available, the ADS-B Report Assembly Function **shall** set the Surveillance Status data provided to the user application to ALL ZEROs.

c. The ADS-B Report Assembly Function **shall** extract the Intent Change Flag (§2.2.3.2.6.1.3 and Figure 2-7, Figure 2-8) from the ADS-B Airborne Velocity Message (§2.2.3.2.6) and map the Intent Change Flag into the bit "b1" of the least significant nibble of the State Vector Report byte on a bit for bit basis as shown in Table 2-81.

d. The ADS-B Report Assembly Function **shall** insert a ZERO (0) into bit "b0" of the least significant nibble of the State Vector Report byte shown in Table 2-81.

2.2.8.1.22 Report Mode

The Report Mode is used to indicate the current state of the Report for each ADS-B vehicle being reported. Each time that the State Vector Report is updated, the Report Mode **shall** be updated with the encoding being as shown in Table 2-87.

Table 2-87: Report Mode Encoding

Coding	Report Mode
xxxx 0000	No Report Generation Capability
xxxx 0001	Acquisition Mode (see §2.2.10.2)
xxxx 0010	Track Mode (see §2.2.10.3)
xxxx 0011 through xxxx 1111	Reserved for Future Expansion

Note: *"x" in the table above, denotes "DON'T CARE."*

2.2.8.2 ADS-B Mode Status Report Characteristics

Table 2-88 and the subsequent subparagraphs identify the data structure for all ADS-B Mode Status Reports.

The Report Assembly Function **shall** be compatible with the current and prior versions of the relevant 1090 MHz ADS-B Messages (e.g., Operational Status, Airborne Position, Surface Position, Airborne Velocity, Aircraft Status and Aircraft Identification) that are used as the basis for generating Mode Status Reports. The relevant Version Two (2) messages are identified below and the relevant Version Zero (0) messages, conformant to RTCA DO-260, including Change 1, and the relevant Version One (1) messages, conformant to RTCA DO-260A, including Change 1 and Change 2, and their required use for ADS-B Mode Status Report generation are defined in Appendix N, Section N.4.

The intent of Table 2-88 is to illustrate the structure of all Items required to be reported in an ADS-B Mode Status Report. The exact structure of the data indicated in columns 10 and 11 is provided as a guideline or one possible method of satisfying the report structure. Implementers may choose to organize the data in another format; however, delivery to a user interface or application of all Items in Table 2-88 **shall** be consistent with the range, resolution, and units indicated in column 7, 8 and 9 of Table 2-88 respectively. If data is not available to support a field that is delivered to an application, then the data provided to the application **shall** be set to ALL ZEROs. Those requirements in §2.2.8.2.1 to §2.2.8.2.4 below that relate to specific data structure details (byte numbers, and bit numbers within the bytes) **shall** only apply to equipment that uses the sample data structure shown in columns 10-11 of Table 2-88.

Note: *Table 2-88 is structured such that column 1, 2, and 6 through 11, pertain to the Mode Status Report elements and how such elements should be structured into the report. Columns 3 through 5 provide information on where the appropriate data can be located in the ADS-B Messages for each of the Report elements.*

Table 2-88: ADS-B Mode Status Data Elements - Source Data Mapping To Report Structure

Table 2-88: ADS-B Mode Status Data Elements – Source Data Mapping To Report Structure											
Column #	**REPORT STRUCTURE**		**MESSAGE STRUCTURE RELEVANT**			**REPORT STRUCTURE RELEVANT**					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Item #	**Parameter / Contents**	**Notes**	**Received Message Sources**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
0a, 0b	Report Type and Structure		N/A	N/A N/A	1 – 5 1 - 5	24	N/A	N/A	discrete	MddL Mddd dddddddd ddddddddL	0 - 2
0c	Validity Flags		N/A	N/A	N/A	8	N/A	N/A	discrete	dddddddd	3
1	Participant Address		Airborne Velocity - "AA" - OR - Operational Status – "AA" - OR - Target State & Status - "AA" - OR - Aircraft ID & Category Msg – "AA"	N/A N/A N/A **N/A**	9 – 32 9 – 32 9 – 32 9 - 32	24 24 24 24	N/A	N/A	discrete	Mddddddd dddddddd ddddddddL	4 – 6
2	Address Qualifier		Aircraft ID & Category "Emitter Category" All Messages with DF=18 – "CF"	6 – 8 N/A	38 – 40 6 – 8	8	N/A	N/A	discrete	xxxxxMdL	7
3	Time of Applicability		Operational Status Airborne Position Target State & Status	N/A	N/A	16	511.9921875	0.0078125 (1/128)	seconds	Mddddddd ddddddddL	8 - 9
4	ADS-B Version		Operational Status – "Version Number"	41 - 43	73 - 75	8	0 - 7	1	discrete	xxxxxMdL	10
5a	Call Sign		Aircraft ID & Category Msg – "Ident Char."	14 – 56	41 – 88	64	N/A	N/A	Alphanumeric characters	xMddddddL xMddddddL xMddddddL xMddddddL xMddddddL xMddddddL xMddddddL xMddddddL	11 – 18
5b	Emitter Category		Aircraft ID & Category Msg – "Emitter Category"	6 – 8	38 - 40	8	N/A	N/A	discrete	xxxMdddL	19
5c	A/V Length and Width Code	3 & 4	Operational Status – Subtype=1 – "L/W Code"	21 – 24	53 – 56	8	N/A	N/A	discrete	xxxxMddL	20
6	Emergency/Priority Status		Aircraft Status Message – Subtype 1 – "Emergency / Priority Status"	9 - 11	36 - 38	8	N/A	N/A	discrete	xxxxxMdL	21
7	Capability Class Codes		Operational Status – "CC" Target State & Status – "TCAS Operational"	9 - 24 53	41 - 56 85	24 1	See §2.2.8.2.10			dddddddd dddddddd dddddddd	22 - 24
8	Operational Mode		Operational Status – "OM"	25 – 40	57 - 72	16	See §2.2.8.2.11			dddddddd dddddddd	25 - 26
9a	SV Quality - NAC_P		Operational Status – "NAC_P" Target State & Status - "NAC_P"	45 – 48 40 - 43	77 – 80 72 - 75	8	N/A	N/A	discrete	xxxxMddL	27

Table 2-88: ADS-B Mode Status Data Elements – Source Data Mapping To Report Structure

Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	**Parameter / Contents**	**Notes**	**Received Message Sources**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
9b	SV Quality - NAC_V		Airborne Velocity – "NAC_V" Operational Status – Subtype=1 – "NAC_V"	11 – 13 17 – 19	43 – 45 49 – 51	8	N/A	N/A	discrete	xxxxxMdL	28
9c	SV Quality – SIL		Operational Status – "SIL" Target State & Status - "SIL"	51 – 52 45 – 46	83 84 77 – 78	8	N/A	N/A	discrete	xxxxxxML	29
9d	SV Quality – SIL Supplement		Operational Status – "SIL Supplement" Target State and Status – "SIL Supplement"	55 8	87 40	8	N/A	N/A	discrete	xxxxxLxx	29
9e	SV Quality – System Design Assurance (SDA)		Operational Status – "SDA"	31 – 32	63 – 64	8	N/A	N/A	discrete	xxxMLxxx	29
9f	SV Quality – GVA		Operational Status – "GVA"	49 – 50	81 – 82	8	N/A	N/A	discrete	xxxxxxML	30
9g	SV Quality – NIC_{BARO}		Operational Status – Subtype=0 – "NIC_{BARO}" Target State & Status - "NIC_{BARO}"	53 44	85 76	8	N/A	N/A	discrete	xxxxxxxL	31
10a	Track/Heading and Horizontal Reference Direction (HRD)		Operational Status – Subtype=1 – Trk/Hdg & Subtype=0,1 – HRD"	53 -54	85 -86	8	N/A	N/A	discrete	xxxxxxML	32
10b	Vertical Rate Type		Airborne Velocity – "Vert. Rate Source"	36	68	8	N/A	N/A	discrete	xxxxxxxL	33
11	(Reserved for) Flight Mode Specific Data					8	N/A	N/A	discrete	xxxxxMdL	34
12	Other (Reserved)		Reserved			8	Reserved			dddddddd	35
										TOTAL BYTES:	36

Notes:

1. *In the "Data Structure" column (i.e., column 10), "S" indicates the "sign-bit," "M" indicates the Most Significant Bit of the data field, "d" indicates data bits in the field, "L" indicates the Least Significant Bit of the data field, and "x" indicates "Don't Care" bits in the data field.*
2. *The Report Type and Structure Identifier is used to identify the type of ADS-B Report being generated and the data parameters provided in the report as specified in §2.2.8.1.1.*
3. *The A/V Length and Width Code parameter is only applicable to Mode Status Reports for aircraft or vehicles that are reporting the surface formats.*
4. *The Operational Mode subfield includes the GPS Antenna Offset parameter in Mode Status Reports for aircraft or vehicles when reporting the surface formats.*

2.2.8.2.1 Mode Status Report Type and Structure Identification and Validity Flags

2.2.8.2.1.1 Mode Status Report Type and Structure Identification

The Report Type requirements were previously provided in §2.2.8.1.1. Report Type formats and the maximum number of bytes to be contained in each report are identified in Table 2-88.

The Report Structure field is used to indicate the exact data parameters identified in Table 2-88 that are being provided in the Mode Status report and is intended to provide a methodology for the Report Assembly Function to structure shorter reports when data for some parameters is not available. In order to provide the capability to provide shorter Mode Status reports the following basic conventions **shall** be adhered to:

a. Any given data parameter to be used in the report **shall** use the designated number of bytes and format as designated in Table 2-88.

b. Parameters that are designated in Table 2-88 are restricted to byte boundaries.

c. Whenever a data parameter identified in Table 2-88 is not provided in the report, then it is permissible to concatenate the next parameter to be included into the report immediately following the inclusion of the previous reported parameter.

d. Each parameter of the Mode Status report identified in Table 2-88 must be properly declared in the Report Structure field as detailed in the following paragraphs and Table 2-89.

Note: *Implementation of the methodology just provided is realizable and controllable due to the fact that the exact length of each report parameter is specified in Table 2-88 and the Report Structure field identifies exactly which parameters are included in the report. Therefore, the report user can easily re-construct the length and general format of the report.*

The Report Structure is a 20-bit field and **shall** be provided in the least significant nibble (i.e., bits 3 - 0) of the first byte (i.e., byte "0") and continuing into bytes 1 and 2 of the Report. The Report Structure format is specified in Table 2-89 where each bit is associated with a particular data parameter of the Mode Status Report. If the bit is set to ONE (1), then the data parameter is considered to be available and **shall** be transmitted in the report. Otherwise, the data parameter is considered to not be available and **shall** not be transmitted in the report. Note that Table 2-89 does not address the Report Type and Structure Identification parameter, the Validity Flags parameter, nor the Participant Address parameter since these four parameters **shall** be included in the Mode Status Report. Also, certain of the other Mode Status data parameters are required to be reported, as specified in §2.2.9, even though bits have been allocated in the report structure field as shown in Table 2-89.

Table 2-89: ADS-B Mode Status Report Structure Coding

Byte #	Bit #	Mode Status Data Parameter to be Reported	Number of Bytes
0	3	Time of Applicability	2
	2	ADS-B Version	1
	1	Call Sign	8
	0	Emitter Category	1
1	7	A/V Length and Width Code	1
	6	Emergency / Priority Status	1
	5	Capability Codes	2
	4	Operational Mode	2
	3	SV Quality - NAC_P	1
	2	SV Quality - NAC_V	1
	1	SV Quality – SIL, SIL Supplement, SDA	1
	0	SV Quality – GVA	1
2	7	SV Quality - NIC_{BARO}	1
	6	True/Magnetic Heading (HRD)	1
	5	Vertical Rate Type	1
	4	(Reserved for) Flight Mode Specific Data	1
	3	Other (Reserved)	1
	2	Reserved	
	1	Reserved	
	0	Reserved	

2.2.8.2.1.2 Mode Status Report Validity Flags

Validity Flags for data provided in the Mode Status Report **shall** be indicated in byte #3 of the Mode Status Report as shown for item “0c” in Table 2-88. The Mode Status Report elements that require validity flags are identified in Table 2-90. Table 2-90 identifies the byte and bit that **shall** be used as a flag for each element that requires a validity flag. Each validity flag bit **shall** be set to ONE (1) to indicate that the corresponding Mode Status Report Element data is valid. If such data is not valid, then the corresponding validity flag bit **shall** be set to ZERO (0). Only the six most significant bits of the subfield are currently assigned. The remaining 2 bits are reserved for future use.

Table 2-90: ADS-B Mode Status Report Validity Flag Requirements

MS Report Item #	Mode Status Report Element	Validity Flag Bit Required?	Validity Flag Bit Assignment Bit #
0a	Report Type	No	
0b	Report Data Structure Definition	No	
0c	Validity Flags	No	
1	Participant Address	No	
2	Address Qualifier	No	
3	Time of Applicability	No	
4	ADS-B Version	No	
5a	Call Sign	No	
5b	Emitter Category	No	
5c	A/V Length and Width Code	No	
6	Emergency/Priority Status	**Yes** If an update has not been received within 100 seconds, via an Extended Squitter Aircraft Status Message, or a Target State and Status Message, then this report element is not considered valid.	2
7	Capability Codes	**Yes** If an update has not been received within 24 seconds, via a Operational Status and/or a Target State and Status Message, then this report element is not considered valid	7 (MSB)
8	Operational Mode	**Yes** If an update has not been received within 24 seconds, via a Operational Status Message, then this report element is not considered valid	6
9a	SV Quality - NAC_P	**Yes** If an update has not been received within 24 seconds, via a Operational Status and/or a Target State and Status Message, then this report element is not considered valid	5
9b	SV Quality - NAC_V	**Yes** If an update has not been received within 24 seconds via Airborne Velocity Message, then this report element is not considered valid	4
9c	SV Quality – SIL	**Yes** If an update has not been received within 24 seconds, via a Operational Status and/or a Target State and Status Message then this report element is not considered valid	3
9d	SV Quality – SIL Supplement	No	
9e	SV Quality – SDA	No	
9f	SV Quality – GVA	No	
9g	SV Quality – NIC_{BARO}	No	
10a	True/Magnetic Heading	No	
10b	Vertical Rate Type	No	
11	(Reserved for) Flight Mode Specific Data	No	
12	Other (Reserved)	No	

2.2.8.2.2 Paritcipant Address

The Participant Address **shall** be encoded as specified in §2.2.3.2.1.5.

2.2.8.2.3 Address Qualifier

The Address Qualifier is used to indicate the type of participant address (§2.2.8.1.3) being reported. The 3 least significant bits of the one byte field are used to convey the Address Qualifier information. The Address Qualifier subfield **shall** be coded as shown in Table 2-85.

2.2.8.2.4 Report Time of Applicability

Each time that an individual Mode Status Report is updated, the Report Assembly Function **shall** update the Report Time of Applicability data in the Mode Status Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Report Time of Applicability data **shall** be provided in the Mode Status report in binary format as specified in Table 2-88.

2.2.8.2.5 Version Number

The ADS-B Report Assembly Function **shall** extract the Version Number data from the ADS-B Aircraft Operational Status Message (§2.2.3.2.7.2.5) and provide the Version Number to the user application in the Mode Status Report in the binary format specified in Table 2-88.

When a valid Version Number is not available, the Version Number sent to the user application **shall** be set to ALL ZEROs.

2.2.8.2.6 Call Sign

The ADS-B Report Assembly Function **shall** first extract the Aircraft Identification Character subfields (§2.2.3.2.5.3) from the ADS-B Flight Identification and Category Message (§2.2.3.2.5.3) for further processing.

Each of the eight characters extracted is encoded in a subset of International Alphabet No. 5 (IA-5) in accordance with §2.2.3.2.5.3. The encoding of each character is 6 bits long with bit_6 being the most significant and bit_1 being the least significant. IA-5 is a seven bit encoding with bit_7 being the most significant and bit_1 being the least significant. In order to provide an IA-5 encoding in an eight bit format as indicated in Table 2-88, the Report Assembly Function **shall**:

(1). Retain bit_6 through bit_1 of the character encoding.

(2). If bit_6 is “ZERO,” set bit_7 to “ONE”

(3). If bit_6 is “ONE,” set bit_7 to “ZERO”

(4). Set bit_8 to “ZERO”

(5). Format bit_8 through bit_6 into "0MdddddL" for entry into the report as shown in Table 2-88.

When valid Flight Identity data is not available, the Call Sign data sent to the user application **shall** be set to ALL ZEROs.

2.2.8.2.7 Emitter Category

The ADS-B Report Assembly Function **shall** extract "TYPE" (§2.2.3.2.5.1) and "ADS-B Emitter Category" (§2.2.3.2.5.2) from the Aircraft Identification and Category Message (§2.2.3.2.5) and encode the "Emitter Category" field of the Mode Status Report as shown in Table 2-91.

Table 2-91: Emitter Category Encoding

Coding (Decimal)	**Meaning**
0	No Emitter Category Information Available
1	Light (<15,500 lbs.)
2	Reserved for Future Growth
3	Small (15,500 to 75,000 lbs.)
4	Reserved for Future Growth
5	Large (75,000 to 300,000 lbs.)
6	High-Vortex Large (aircraft such as B-757)
7	Heavy (>300,000 lbs.)
8	High Performance (>5 g acceleration ***and*** >400 knots)
9	Reserved for Future Growth
10	Rotorcraft
11	Glider / Sailplane
12	Lighter - than - Air
13	Unmanned Aerial Vehicle
14	Space / Trans-atmospheric Vehicle
15	Ultralight / hang-glider / paraglider
16	Parachutist / Skydiver
17	Reserved for Future Growth
18	Reserved for Future Growth
19	Reserved for Future Growth
20	Surface Vehicle - Emergency Vehicle
21	Surface Vehicle - Service Vehicle
22	Point Obstacle (includes Tethered Ballons)
23	Cluster Obstacle
24	Line Obstacle
25 through 31	Reserved for Future Growth

When valid ADS-B Emitter Category data is not available, the Emitter Category data sent to the user application **shall** be set to ALL ZEROs.

2.2.8.2.8 Aircraft/Vehicle (A/V) Length and Width Code

The ADS-B Report Assembly Function **shall** extract the Aircraft/Vehicle (A/V) Length and Width Code from the Aircraft Operational Status Message (§2.2.3.2.7.2) when the A/V is on the airport surface. The A/V Length and Width Code **shall** be encoded bit for bit as specified in Table 2-74, into the Mode Status Report as specified in Table 2-88.

2.2.8.2.9 Emergency / Priority Status

The ADS-B Report Assembly Function **shall** extract the "Emergency / Priority Status" data from the Extended Squitter Aircraft Status Message (§2.2.3.2.7.8.1) (TYPE=28, Subtype=1), and provide that Emergency / Priority Status information to the user application in the Mode Status Report in the binary format specified in Table 2-88.

"Emergency/Priority Status," bits 9 - 11 (see Appendix A, Figure A-8), of the Extended Squitter Aircraft Status Message **shall** be mapped bit for bit into the three least significant bits of the report byte as indicated in Table 2-88.

When valid "Emergency/Priority Status" data is not available (i.e., has not been received within the past 100 seconds as per Table 2-102, Note #5), then the Emergency/Priority Status data sent to the user application **shall** be set to ALL ZEROs and flagged as being "invalid" as per Table 2-90.

2.2.8.2.10 Capability Class Codes

The ADS-B Report Assembly Function **shall** extract the "Capability Class Codes" data (§2.2.3.2.7.2.3) and the Target State and Status Message from the Aircraft Operational Status Message (§2.2.3.2.7.2) and provide the Capability Class Codes to the user application in the Mode Status Report in the binary format specified in Table 2-88.

Capability Class Codes from the ADS-B Operational Status and the Target State and Status Messages, **shall** be mapped bit for bit into the 3-byte long Capability Class Codes field of the ADS-B Mode Status Report as specified in Table 2-92.

When valid "Capability Class" data is not available for a given parameter, then the Capability Class data sent to the user application for that parameter **shall** be set to ALL ZEROs.

When a Mode Status Report is generated and when the only received update to the "Capability Class" data has come from a Target State and Status Message, the reported value of all Capability Class parameters **shall** be based on the most recently received Operational Status Message, except updated with the data (i.e., TCAS parameter) received in the subsequent Target State and Status Message.

Table 2-92: Capability Code Mapping

MS Report			Operational Status Message Subtype 0 (Airborne)		Operational Status Message Subtype 1 (Surface)		Target State and Status Message	
MS Report CC Field Byte #	Bit #	Parameter	Msg. Bit # (ME field)	Mapping to MS Report	Msg. Bit # (ME field)	Mapping to MS Report	Msg. Bit # (ME field)	Mapping to MS Report
0	7	Reserved	9	Direct Mapping	9	Direct Mapping		
	6		10	Direct Mapping	10	Direct Mapping		
	5		13	Direct Mapping	13	Direct Mapping		
	4		14	Direct Mapping	14	Direct Mapping		
	3	B2 Low			15	Direct Mapping		
	2	Reserved						
	1	Reserved						
	0	Reserved						
1	7	TCAS Operational	11	Direct Mapping			53	Direct Mapping
	6	1090ES IN	12	Direct Mapping	12	Direct Mapping		
	5	ARV	15	Direct Mapping				
	4	TS Report	16	Direct Mapping				
	3	TC Report	17	Direct Mapping				
	2		18	Direct Mapping				
	1	POA			19	Direct Mapping		
	0	UAT IN	19	Direct Mapping	16	Direct Mapping		
2	7	Reserved						
	6	Reserved						
	5	Reserved						
	4	Reserved						
	3	Reserved						
	2	Reserved						
	1	Reserved						
	0	Reserved						

Note: *Direct Mapping means the message bit state (i.e., 0 or 1) remains the same when mapped into the Mode Status Report. Inverse Mapping means the message bit state is reversed when mapped into the Mode Status Report.*

2.2.8.2.11 Operational Mode

The ADS-B Report Assembly Function **shall** extract the "Operational Mode" data, "ME" bits 25 through 40, (see Table 2-68 and §2.2.3.2.7.2.4) from the Aircraft Operational Status Message (§2.2.3.2.7.2) and **shall** be mapped bit for bit into the 2-byte long Operational Mode field of the ADS-B Mode Status Report in the binary format specified in Table 2-88.

Operational Mode Codes from the ADS-B Aircraft Operational Status Message **shall** be mapped bit for bit into the 2-byte long Operational Mode Codes subfield of the ADS-B Mode Status Report as specified in Table 2-92A.

Table 2-92A: Operational Mode Code Mapping

MS Report			Operational Status Message Subtype 0 (Airborne)	Operational Status Message Subtype 1 (Surface)
MS Report OM Field Byte #	**Bit #**	**Parameter**	**Msg. Bit # (ME field)**	**Msg. Bit # (ME field)**
0	7	OM Format	25	25
	6	OM Format	26	26
	5	TCAS RA Active	27	27
	4	IDENT Switch	28	28
	3	Reserved for Receiving ATC Services	29	29
	2	Single Antenna Flag	30	30
	1	Reserved		
	0	Reserved		
1	7	GPS Antenna Offset		33
	6			34
	5			35
	4			36
	3			37
	2			38
	1			39
	0			40

2.2.8.2.12 SV Quality – NAC_P

The ADS-B Report Assembly Function **shall** extract the NAC_P data from the Aircraft Operational Status Message (§2.2.3.2.7.2) and from the Target State and Status Message (§2.2.3.2.7.1.3.8) and map the NAC_P value bit for bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

2.2.8.2.13 SV Quality – NAC_V

The ADS-B Report Assembly Function **shall** extract the NAC_V data from the ADS-B Airborne Velocity Message (§2.2.3.2.6), and the Aircraft Operational Status Message (§2.2.3.2.7.2), and map the NAC_V value bit for bit from the received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

2.2.8.2.14 SV Quality – SIL, SIL Supplement, SDA

2.2.8.2.14.1 SV Quality – Source Integrity Level (SIL)

The ADS-B Report Assembly Function **shall** extract the SIL data from the Aircraft Operational Status Message (§2.2.3.2.7.2.9) and from the Target State and Status Message (§2.2.3.2.7.1.3.10), and map the SIL Value bit for bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

2.2.8.2.14.2 SV Quality – SIL Supplement

The ADS-B Report Assembly Function **shall** extract the SIL Supplement data from the Aircraft Operational Status Message (§2.2.3.2.7.2.14) and from the Target State and Status Message (§2.2.3.2.7.1.3.1), and map the SIL Supplement value bit for bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

2.2.8.2.14.3 SV Quality – System Design Assurance (SDA)

The ADS-B Report Assembly Function **shall** extract the SDA data from the Aircraft Operational Status Message (§2.2.3.2.7.2.4.6) and map the SDA value bit for bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

2.2.8.2.15 SV Quality – GVA

The ADS-B Report Assembly Function **shall** extract the GVA data from the Aircraft Operational Status Message (§2.2.3.2.7.2.8) and map the value of the GVA field to the Mode Status Report in the format specified in Table 2-88.

2.2.8.2.16 SV Quality – NIC_{BARO}

The ADS-B Report Assembly Function **shall** extract the NIC_{BARO} data from the Aircraft Operational Status Message (§2.2.3.2.7.2.10) and from the Target State and Status Message (§2.2.3.2.7.1.3.9), and map the value of the NIC_{BARO} bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88. The NIC_{BARO} field in the Mode Status Report uses the least significant bit of a one-byte field as a one-bit flag that indicates whether or not the barometric pressure altitude that is provided in the State Vector Report has been cross-checked against another source of altitude.

2.2.8.2.17 Track/Heading and Horizontal Reference Direction (HRD)

The ADS-B Report Assembly Function **shall** extract the Track Angle/Heading (§2.2.3.2.7.2.12) and the Horizontal Reference Direction (HRD) (§2.2.3.2.7.2.13) flag bits from the Aircraft Operational Status Message (§2.2.3.2.7.2) and set the True/Magnetic Heading field in the Mode Status Report in the binary format specified in Table 2-88. This item within the Mode Status Report is used to indicate the nature of the Horizontal Direction information being reported in the State Vector Reports. This applies to the aircraft reported Horizontal Direction (in the State Vector Report). The encoding of bits 0 and 1 of the report True/Magnetic Heading field **shall** be as specified in Table 2-93. Bit 1 of the True/Magnetic Heading field indicates when Ground Track is being reported (i.e., set to zero) or when Heading is being reported (i.e., set to one). Bit 0 of the True/Magnetic Heading field indicates when Heading based on True North (i.e., set to zero) or when heading based on Magnetic North (i.e., set to one) is being reported.

Table 2-93: True/Magnetic Heading Encoding

Coding		Meaning
bit 1	**bit 0**	
0	0	No Track/Heading or HRD Information Available
0	1	Ground track being reported
1	0	Heading relative to true north being reported
1	1	Heading relative to magnetic north being reported

Note: *Bits 2 through 7 of byte 32 of the True/Magnetic Heading subfield are always set to ZERO (0).*

2.2.8.2.18 Vertical Rate Type

The ADS-B Report Assembly Function **shall** extract the Vertical Rate Source (§2.2.3.2.6.1.10, §2.2.3.2.6.2.10, §2.2.3.2.6.3.10, §2.2.3.2.6.4.10) data from the ADS-B Airborne Velocity Message (§2.2.3.2.6) and set the Vertical Rate Type in the Mode Status Report in the binary format specified in Table 2-88. The Vertical Rate Type field uses the least significant bit of a one-byte field in the Mode Status Report. This one-bit flag **shall** be set to ZERO (0) to indicate that the Vertical Rate field in the State Vector Report holds the rate of change of barometric pressure altitude. Or, this one-bit flag **shall** be set to ONE (1) to indicate that the Vertical Rate field holds the rate of change of geometric altitude.

2.2.8.2.19 (Reserved for) Flight Mode Specific Data

A 3-bit field in the Mode Status Report is reserved for future use as a “Flight Mode Specific Data” field. In the current version of these MOPS, this field **shall** be set to ALL ZEROs.

2.2.8.3 ADS-B On-Condition Report Characteristics

ADS-B On-Condition Reports include, but will not necessarily be limited to:

a. The Target State Report

b. The Air Referenced Velocity Report

Note: *It is anticipated that the Trajectory Change Reports will be specified by a future revision of these MOPS as an additional type of "On-Condition" Report.*

2.2.8.3.1 ADS-B Target State Report

Table 2-94 and the subsequent subparagraphs identify the data structure for all ADS-B Target State Reports.

The Report Assembly Function **shall** be compatible with the current ADS-B Version Two (2) of the relevant 1090 MHz ADS-B Messages (e.g., Target State and Status, Subtype=1) that are used as the basis to generate Target State Reports. The relevant Version Two (2) messages are identified below.

Note: *Version 0 messages cannot be used as the basis for Target State Reports, because there are no Version 0 messages that contain the necessary data elements. Version 1 message formats for the Target State and Status Message with Subtype=0 are defined in Appendix N, but are not used to generate the Version 2 Target State Report .*

The intent of Table 2-94 is to illustrate the structure of all Items that are required to be reported in an ADS-B Target State Report. The exact structure of the data indicated in columns 10 and 11 is provided as a guideline or one possible method of satisfying the report structure. Implementers may choose to organize the data in another format; however, delivery to a user interface or application of all Items in Table 2-94 **shall** be consistent with the range, resolution, and units indicated in column 7, 8 and 9 of Table 2-94 respectively. If data is not available to support a field that is delivered to an application, then the data provided to the application **shall** be set to ALL ZEROs. Those requirements in the subparagraphs below that relate to specific data structure details (byte numbers, and bit numbers within the bytes) **shall** only apply to equipment that uses the sample data structure shown in columns 10 and 11 of Table 2-94.

Note: *Table 2-94 is structured such that column 1, 2, and 6 through 11, pertain to the Target State Report elements and how such elements should be structured into the report. Columns 3 through 5 provide information on where the appropriate data can be located in the ADS-B Messages for each of the Report elements.*

Table 2-94: ADS-B Target State Data Elements - Source Data Mapping To Report Structure

Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	**Parameter / Contents**	**Notes**	**Received Message Sources**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
0a, 0b	Report Type and Structure Identification	3	N/A	N/A	1 - 5	16	N/A	N/A	discrete	MddL Mddd ddddddL	0 - 1
0c	Validity Flags		N/A	N/A	N/A	16	N/A	N/A	discrete	dddddddd ddddddd	2 – 3
1	Participant Address		Target State & Status - "AA"	N/A	9 - 32	24	N/A	N/A	discrete	Mddddddd dddddddd ddddddL	4 – 6
2	Address Qualifier		Aircraft ID & Category "Emitter Category" All Messages with DF=18 – "CF"	6 – 8 N/A	38 – 40 6 – 8	8	N/A	N/A	discrete	xxxxxMdL	7
3	Report Time of Applicability		Target State & Status	N/A	N/A	16	511.9921875	0.0078125 (1/128)	seconds	Mddddddd ddddddL	8 – 9
4a	Selected Altitude: Selected Altitude Type		Target State & Status – "Selected Altitude Type"	9	41	8	N/A	N/A	discrete	xxxxxxxL	10
4b	Selected Altitude: MCP/FCU Selected Altitude or FMS Selected Altitude		Target State &Status – "MCP/FCU Selected Altitude or FMS Selected Altitude"	10 - 20	42 - 52	16	0 - 65472	32	feet	xxxxxMdd ddddddL	11 – 12
4c	Selected Altitude: Barometric Pressure Setting (Minus 800 millibars)		Target State & Status – "Selected Altitude: Barometric Pressure Setting (Minus 800 millibars)"	21 - 29	53 - 61	16	0- 408.0	0.8	Milli bars	xxxxxxxM ddddddL	13 - 14
5	Selected Heading		Target State & Status – "Selected Heading"	31 - 39	63 - 71	16	±180	0.703125	degrees	xxxxxxxS MddddddL	15 - 16
6a	Mode Indicators: Autopilot Engaged		Target State & Status – "Autopilot Engaged"	48	80	8	N/A	N/A	discrete	xxxxxxxL	17
6b	Mode Indicators: VNAV Mode Engaged		Target State & Status – "VNAV Mode Engaged"	49	81	8	N/A	N/A	discrete	xxxxxxxL	18
6c	Mode Indicators: Altitude Hold Mode		Target State & Status – "Altitude Hold Mode"	50	82	8	N/A	N/A	discrete	xxxxxxxL	19
6d	Mode Indicators: Approach Mode		Target State & Status – "Approach Mode"	52	84	8	N/A	N/A	discrete	xxxxxxxL	20
7	Reserved		N/A			8	N/A	N/A	discrete	xxxxxxxx	21
										TOTAL BYTES:	**21**

Notes:

1. *In the "Data Structure" column (i.e., column 10), "S" indicates the "Sign-Bit," "M" indicates the Most Significant Bit of the data field, "d" indicates data bits in the field, "L" indicates the Least Significant Bit of the data field, and "x" indicates "Don't Care" bits in the data field.*

2. *The Report Type Identifier is used to identify the type of ADS-B Report being generated as specified in §2.2.8.1.1.1.*

2.2.8.3.1.1 Report Type and Structure Identification

The Report Type requirements were previously provided in §2.2.8.1.1. Report Type formats and the maximum number of bytes to be contained in each report are identified in Table 2-94.

The Report Structure field is used to indicate the exact data parameters identified in Table 2-94 that are being provided in the Target State Report and is intended to provide a methodology for the Report Assembly Function to structure shorter reports when data for some parameters is not available. In order to provide the capability to provide shorter Target State Reports the following basic conventions **shall** be adhered to:

a. Any given data parameter to be used in the report **shall** use the designated number of bytes and format as designated in Table 2-94.

b. Parameters that are designated in Table 2-94 are restricted to byte boundaries.

c. Whenever a data parameter identified in Table 2-94 is not provided in the report, then it is permissible to concatenate the next parameter to be included into the report immediately following the inclusion of the previous reported parameter.

d. Each parameter of the Target State Report identified in Table 2-94 must be properly declared in the Report Structure field as detailed in the following paragraphs and Table 2-95.

Note: *Implementation of the methodology just provided is realizable and controllable due to the fact that the exact length of each report parameter is specified in Table 2-94 and the Report Structure field identifies exactly which parameters are included in the report. Therefore, the report user can easily re-construct the length and general format of the report.*

The Report Structure is a 12-bit field and **shall** be provided in the least significant nibble (i.e., bits 3 - 0) of the first byte (i.e., byte “0”) and continuing into byte 1 of the Report. The Report Structure format is specified in Table 2-95 where each bit is associated with a particular data parameter of the Target State Report. If the bit is set to ONE (1), then the data parameter is considered to be available and **shall** be transmitted in the report. Otherwise, the data parameter is considered to not be available and **shall** not be transmitted in the report. Note that Table 2-95 does not address the Report Type and Structure Identification parameter, the Participant Address parameter, the Address Qualifier parameter, nor the Report Time of Applicability parameter, since these four parameters **shall** be included in the Target State Report. Also, certain of the other Target State data parameters are required to be reported, as specified in §2.2.9, even though bits have been allocated in the report structure field as shown in Table 2-95.

Table 2-95: ADS-B Target State Report – Structure Parameter Coding

Byte #	Bit #	Target State Data Parameter to be Reported	Number of Bytes
0	3	Selected Altitude: Selected Altitude Type	1
	2	Selected Altitude: MCP/FCU Selected Altitude or FMS Selected Altitude	2
	1	Selected Altitude: Barometric Pressure Setting (Minus 800 millibars)	2
	0	Selected Heading	2
1	7	Mode Indicators: Autopilot Engaged	1
	6	Mode Indicators: VNAV Mode Engaged	1
	5	Mode Indicators: Altitude Hold Mode	1
	4	Mode Indicators: Approach Mode	1
	3	Reserved	x
	2	Reserved	x
	1	Reserved	x
	0	Reserved	x

2.2.8.3.1.2 Target State and Status Validty Flags

Validity Flags for data provided in the Target State Report **shall** be indicated in bytes #3 and #4 of the Target State Report as shown for item “0c” in Table 2-95A. The Target State Report elements that require Validity Flags are identified in Table 2-95A. Table 2-95A identifies the byte and bit that **shall** be used as a flag for each element that requires a validity flag. Each Validity Flag bit **shall** be set to ONE (1) to indicate that the corresponding State Vector Report Element data is valid. If such data is not valid, then the corresponding Validity Flag bit **shall** be set to ZERO (0).

Table 2-95A: ADS-B Target State Report Validity Flag Requirements

TS Report Item #	Target State Report Element	Validity Flag Bit Required?	Validity Flag Bit Assignment	
0a	Report Type	No	**Byte #**	**Bit #**
0b	Structure Identification	No		
0c	Validity Flags	No		
1	Participant Address	No		
2	Address Qualifier	No		
3	Report Time of Applicability	No		
4a	Selected Altitude Type	No		
4b	MCP/FCU Selected Altitude or FMS Selected Altitude	**Yes** (This validity flag bit is for Selected Altitude Valid)	3	7
4c	Barometric Pressure Setting (Minus 800 millibars)	**Yes** (This bit is validity flag bit for Barometric Pressure Setting Valid)	3	6
5	Selected Heading	**Yes** (This bit is validity flag bit for Selected Heading Valid)	3	5
6	MCP / FCU Mode Bits Status	**Yes** (This bit is validity flag bit for MCP / FCU Mode Bits Valid)	3	4

2.2.8.3.1.3 Participant Address

The Participant Address **shall** be encoded as specified in §2.2.3.2.1.5.

2.2.8.3.1.4 Address Qualifier

The Address Qualifier is used to indicate the type of Participant Address (§2.2.8.1.3) being reported. The three (3) least significant bits of the one-byte field are used to convey the Address Qualifier information. The Address Qualifier subfield **shall** be coded as shown in Table 2-85.

2.2.8.3.1.5 Report Time of Applicability

Each time that an individual Target State Report is updated, the Report Assembly Function **shall** update the Time of Applicability data in the On - Condition Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Report Time of Applicability data **shall** be provided in the Target State Report in binary format as specified in Table 2-94.

2.2.8.3.1.6 Selected Altitude: Selected Altitude Type

The Selected Altitude Type parameter **shall** use the least significant bit within byte 10 to encode the parameter values specified in §2.2.3.2.7.1.3.2.

2.2.8.3.1.7 Selected Altitude: MCP/FCU Selected Altitude or FMS Selected Altitude

The MCP / FCU Selected Altitude or FMS Selected Altitude parameter **shall** use the three (3) least significant bits within byte 11 and the 8 bits of byte 12 to encode the parameter values specified §2.2.3.2.7.1.3.3.

2.2.8.3.1.8 Selected Altitude: Barometric Pressure Setting (Minus 800 millibars)

The Barometric Pressure Setting (Minus 800 millibars) parameter **shall** use the three (3) least significant bits within byte 13 and the 8 bits of byte 14 to encode the patameter values specified in §2.2.3.2.7.1.3.4.

2.2.8.3.1.9 Selected Heading

The Selected Heading parameter **shall** use the least significant bit of byte 15 and the 8 bits of byte 16 to encode the heading values specified in §2.2.3.2.7.1.3.7.

2.2.8.3.1.10 Mode Indicators: Autopilot Engaged

The Autopilot Engaged parameter **shall** use the least significant bit within byte 17 to encode the parameter values specified in §2.2.3.2.7.1.3.12.

2.2.8.3.1.11 Mode Indicators: VNAV Mode Engaged

The VNAV Mode Engaged parameter **shall** use the least significant bit within byte 18 to encode the parameter values specified in §2.2.3.2.7.1.3.13.

2.2.8.3.1.12 Mode Indicators: Altitude Hold Mode

The Altitude Hold Mode parameter **shall** use the least significant bit within byte 19 to encode the parameter values specified in §2.2.3.2.7.1.3.14.

2.2.8.3.1.13 Mode Indicators: Approach Mode

The Approach Mode parameter **shall** use the least significant bit within byte 20 to encode the parameter values specified in §2.2.3.2.7.1.3.16.

2.2.8.3.1.14 Reserved

A one-byte parameter is reserved for possible future use.

2.2.8.3.2 Air Referenced Velocity (ARV) Report

The Air Referenced Velocity (ARV) Report is an On-Condition Report type that **shall** be provided when air-referenced velocity information is received from a target aircraft.

The Report Assembly Function **shall** be compatible with the current and prior versions of the relevant 1090 MHz ADS-B Messages (e.g., Airborne Velocity) that are used to as the basis to generate Air Referenced Velocity Reports. The relevant Version Two (2) messages are identified below and the relevant Version Zero (0) messages, conformant to RTCA DO-260, including Change 1, and the relevant Version One (1) messages, conformant to RTCA DO-260A, including Change 1 and Change 2, and their required use for Air Referenced Velocity Report generation are defined in Appendix N, Section N.5.

If data is not available to support a field that is delivered to an application, then the data provided to the application **shall** be set to ALL ZEROs. Table 2-96 and the subsequent subparagraphs describe the data structure for all ARV Reports.

Table 2-96: ADS-B Air Referenced Velocity Data Elements - Source Data Mapping To Report Structure

Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	Parameter / Contents	Notes	Received Message Sources	"ME" Field Bits	Message Field Bits	# of Bits	Range	Resolution	Units	Data Structure	Data Byte #
0a, 0b	Report Type and Structure Identification		N/A	N/A	1 - 5	16	N/A	N/A	discrete	MddL xxxx xxxxMddL	0 - 1
0c	Validity Flags		N/A	N/A	N/A	8	N/A	N/A	discrete	xxxxxxML	2
1	Participant Address		Airborne Velocity Subtype 3 or 4 – "AA"	N/A	9 - 32	24	N/A	N/A	discrete	Mddddddd dddddddd dddddddL	3 - 5
2	Address Qualifier		Aircraft ID & Category "Emitter Category" All Messages with DF=18 – "CF"	6 – 8 N/A	38 – 40 6 – 8	8	N/A	N/A	discrete	xxxxxMdL	6
3	Report Time of Applicability		Airborne Velocity Subtypes 3 or 4–	N/A	N/A	16	511.9921875	0.0078125 (1/128)	seconds	Mddddddd dddddddL	7 - 8
4a	Airspeed	3	Airborne Velocity - Subtype 3 – "Airspeed" - OR - Subtype 4 - "Airspeed"	26 – 35 26 - 35	58 – 67 58 - 67	16 16	0 – 1000 1001 - 4000	1 4	knots knots	xxxxMddd dddddddL xxxxMddd dddddL00	9 - 10
4b	Airspeed Type		Airborne Velocity - Subtype 3 – "Airspeed Type"	25	57	8	N/A	N/A	discrete	xxxxxxML	11
5	Heading While Airborne		Airborne Velocity - Subtype 3 – "Heading"	15 - 24	47 - 56	16	0 – 359.6484375	0.3515625 (360/1024)	degrees	xxxxxxMd dddddddL	12 - 13
										TOTAL BYTES	**14**

Notes:

1. *In the "Data Structure" column (i.e., column 10), "S" indicates the "Sign-Bit," "M" indicates the Most Significant Bit of the data field, "d" indicates data bits in the field, "L" indicates the Least Significant Bit of the data field, "0" indicates the bit is to always be set to a value of ZERO (0), and "x" indicates "Don't Care" bits in the data field.*

2. *The Report Type Identifier is used to identify the type of ADS-B Report being generated as specified in §2.2.8.1.1.1.*

3. *Airspeed is coded with a fixed data structure using the 12 least significant bits of the 2-byte field. For the case where the source message for the air-referenced velocity information is of the type Airborne Velocity – Subtype 3 (§2.2.3.2.6.3), a reported resolution of 1 knot is used for airspeed. This generally applies for aircraft airspeeds of 0 to 1000 knots, although under certain conditions, as described in §2.2.3.2.6.3, an airspeed of up to 1022 knots may be reported with 1 knot resolution. For airspeeds greater than 1000 knots and where the source message for the air-referenced velocity information is of the type Airborne Velocity – Subtype 4 (§2.2.3.2.6.4), the two least significant bits are set to a value of ZERO (0) thus providing an actual reported resolution of 4 knots.*

2.2.8.3.2.1 Report Type and Structure Identification and Validity Flags

2.2.8.3.2.1.1 Report Type and Structure Identification

The Report Type requirements were previously provided in §2.2.8.1.1.1. The Report Type is provided in the most significant nibble of the first byte of the report. The Report Type format, coding and the maximum number of bytes (i.e., 13 bytes) to be contained in each Air Referenced Velocity report are identified in Table 2-96.

The Report Structure field is used to indicate the exact data parameters identified in Table 2-96 that are being provided in the Air Referenced Velocity report and is intended to provide a methodology for the Report Assembly Function to structure shorter reports when data for some parameters is not available. In order to provide the capability to provide shorter Air Referenced Velocity reports the following basic conventions **shall** be adhered to:

a. Any given data parameter to be used in the report **shall** use the designated number of bytes and format as designated in Table 2-96.

b. Parameters that are designated in Table 2-96 are restricted to byte boundaries.

c. Whenever a data parameter identified in Table 2-96 is not provided in the report, then it is permissible to concatenate the next parameter to be included into the report immediately following the inclusion of the previous reported parameter.

d. Each parameter of the Air Referenced Velocity report identified in Table 2-96 must be properly declared in the Report Structure field as detailed in the following paragraphs and Table 2-97.

Note: *Implementation of the methodology just provided is realizable and controllable due to the fact that the exact length of each report parameter is specified in Table 2-96 and the Report Structure field identifies exactly which parameters are included in the report. Therefore, the report user can easily re-construct the length and general format of the report.*

The Report Structure Identification parameter is a 12-bit field and **shall** be encoded in the least significant nibble (i.e., bits 3 through 0) of the first byte (i.e., byte "0") and continuing into byte 1 of the Report. The Report Structure Identification parameter format is specified in Table 2-95 where each bit is associated with a particular subsequent data parameter of the Air Referenced Velocity Report. If the bit is set to ONE (1), then the data parameter is considered to be available and **shall** be transmitted in the report. Otherwise, the data parameter is considered to not be unavailable and **shall** not be transmitted in the report. Note that Table 2-97 does not address the Report Type and Structure Identification parameter, the Participant Address parameter, the Address Qualifier parameter, and the Report Time of Applicability parameter **since these four parameters shall be included in each Air Referenced Velocity Report**. **Also certain of the other Air Referenced Velocity data parameters are required to be reported, as specified in §2.2.9.1, even though bits have been allocated in the report structure field as shown in Table 2-97.**

Table 2-97: ADS-B Air Referenced Velocity Report – Structure Parameter Coding

Byte #	Bit #	Air Referenced Velocity Data Parameter to be Reported	Number of Bytes
0	3 - 7	Reserved	N/A
	2	Airspeed	2
	1	Airspeed Type and Validity	1
	0	Heading While Airborne	2

2.2.8.3.2.1.2 ARV Report Validity Flags

The only Validity Flag specified by these MOPS for the Air Referenced Velocity Report uses the two (2) least significant bits of the one-byte field as shown in Table 2-98.

Table 2-98: ADS-B Air Referenced Velocity Report – Validity Flag Coding

Byte #	Bit #	Validity Flag Reported
2	2 – 7	Reserved
	1	Airspeed Valid
	0	Heading Valid

The "Heading Valid" flag bit in the ARV report **shall** be set to ONE if the "Heading While Airborne" field contains valid heading information, or set to ZERO if that field is known to not contain valid heading information. The reported heading **shall** be indicated as not valid if the received ADS-B Airborne Velocity Message (§2.2.3.2.6.3 or §2.2.3.2.6.4) includes a "Heading Status Bit" (§2.2.3.2.6.3.6) indicating that "Heading Data is NOT Available."

The "Airspeed Valid" flag bit **shall** be set to ONE if the "Airspeed" field (§2.2.8.3.2.6) contains valid heading information, or ZERO if that field is known to not contain valid airspeed information. The reported Airspeed **shall** be indicated as "Not Valid" if the received ADS-B Airborne Velocity Message (§2.2.3.2.6.3 or §2.2.3.2.6.4) includes either a value for the "Airspeed" subfield indicating "No Airspeed Information Available," or includes a value for the "NAC_V" subfield that is invalid.

2.2.8.3.2.2 Participant Address

The participant address **shall** be encoded as specified in §2.2.3.2.1.5.

2.2.8.3.2.3 Address Qualifier

The Address Qualifier is used to indicate the type of Participant Address (§2.2.8.1.3) being reported. The 3 least significant bits of the one-byte field are used to convey the Address Qualifier information. The Address Qualifier subfield **shall** be coded as specified in Table 2-85.

2.2.8.3.2.4 Report Time of Applicability

Each time that an individual Air Referenced Velocity Report is updated, the Report Assembly Function **shall** update the Time of Applicability data in the Air Referenced Velocity Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Report Time of Applicability data **shall** be provided in the Air Referenced Velocity report in binary format as specified in Table 2-96.

2.2.8.3.2.5 Airspeed

Airspeed **shall** be reported over the range of 0 to 4000 knots. The Airspeed parameter is coded with a fixed data structure using the 4 least significant bits of the first byte and the 8 bits of the second byte of the Airspeed field as identified in Table 2-96. For the case where the source message for the Air-Referenced Velocity information is of the type Airborne Velocity Message – Subtype=3 (§2.2.3.2.6.3), a reported resolution of 1 knot is used for Airspeed. This generally applies for Aircraft Airspeeds of 0 to 1000 knots, although under certain conditions, as described in §2.2.3.2.6.3, an Airspeed of up to 1022 knots may be reported with 1 knot resolution. For Airspeeds greater than 1000 knots and where the source message for the Air-Referenced Velocity information is of the type Airborne Velocity Message – Subtype=4 (§2.2.3.2.6.4), the two (2) least significant bits are set to a value of ZERO (0) thus providing an actual reported resolution of 4 knots.

2.2.8.3.2.6 Airspeed Type

The Airspeed Type and Validity field in the Air Referenced Velocity Report is a 2-bit field that **shall** be encoded as specified in Table 2-99. The type of Airspeed being reported **shall** be obtained from the "Airspeed Type" subfield of the ADS-B Airborne Velocity Message, Subtype=3 (§2.2.3.2.6.3) or Subtype=4 (§2.2.3.2.6.4). The reported Airspeed **shall** be indicated as "Not Valid" if the received ADS-B Airborne Velocity Message (§2.2.3.2.6.3 or §2.2.3.2.6.4) includes either a value for the "Airspeed" subfield indicating "No Airspeed Information Available," or includes a value for the "NAC_V" subfield that is invalid. When set to indicate the "Airspeed Field is Not Valid," the corresponding Validity Flag parameter (§2.2.8.3.2.1.2) **shall** also be set to indicate that the reported Airspeed is not valid.

Table 2-99: Airspeed Type Encoding

Coding	Meaning
00	Airspeed Field Not Valid
01	True Airspeed (TAS)
10	Indicated Airspeed (IAS)
11	Reserved for Mach

2.2.8.3.2.7 Heading While Airborne

An Aircraft's Heading is reported as the angle measured clockwise from the reference direction (magnetic north) to the direction in which the Aircraft's nose is pointing. The heading field in Air Reference Velocity Reports **shall** be encoded using the 2 least significant bits of the first byte and the 8 bits of the second byte of the "Heading While Airborne" field as specified in Table 2-96. The encoding **shall** be the same as that used in the "Heading" subfield of the ADS-B Airborne Velocity Message – Subtype=3 as specified in §2.2.3.2.6.3.7.

2.2.8.4 Processing of Reserved Message TYPE Codes

Receivers shall meet the requirements of §2.2.8.1 through §2.2.8.3 when receiving any valid combination of messages with "TYPE" Codes 0 through 31 including TYPE Codes 24, 25, 26, 27 and 30.

Note: *This requirement ensures that the receipt of ADS-B Messages with reserved "TYPE" Codes will not adversely affect the processing of other ADS-B Messages*.

2.2.8.5 Receiving Installation Time Processing

2.2.8.5.1 Precision Installations

Receiving devices intended to generate ADS-B reports based on Surface Position Messages received from TYPE 5 or 6 (see §2.2.3.2.3.1) equipment or Airborne Position Messages received from TYPE 9, 10, 20 or 21 (see §2.2.3.2.3.1) equipment **shall** accept GPS/GNSS UTC Measure Time data via an appropriate interface. Such data **shall** be used to establish Time of Applicability data required in §2.2.8.1.4, §2.2.8.1.17 through §2.2.8.1.20, §2.2.8.2.4, §2.2.8.3.1.5 and §2.2.8.3.2.4.

UTC Measure Time data **shall** have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) seconds.

Note: *Time of Applicability information is required in Item #'s 18 through 23, and 25 of Table 2-81, Item #16 of Table 2-88, and Item #7 of Table 2-94. Each of these table entries specify the data to be entered in 9 bits of whole number and 7 bits of fractional data. Therefore, the full range can be up to 511.9921875 seconds having the required resolution of 0.0078125 seconds.*

2.2.8.5.2 Non-Precision Installations

Receiving devices that are not intended to generate ADS-B reports based on Surface Position Messages received from TYPE 5 or 6 (see §2.2.3.2.3.1) equipment or Airborne Position Messages received from TYPE 9, 10, 20 or 21 (see §2.2.3.2.3.1) equipment may choose not to use GPS/GNSS UTC Measure Time data if there is no requirement to do so by the end user of the ADS-B reports. In such cases, where there is no appropriate time reference, the Receiving device **shall** establish an appropriate internal clock or counter having a maximum clock cycle or count time of 20 milliseconds. The established cycle or clock count **shall** have a range of 300 seconds and a resolution of 0.0078125 (1/128) seconds in order to maintain commonality with the requirements of §2.2.8.5.1.

Note: *Time of Applicability information is required in Item #'s 18 through 23, and 25 of Table 2-81, Item #16 of Table 2-88, and Item #7 of Table 2-94. Each of these table entries specify the data to be entered in 9 bits of whole number and 7 bits of fractional data. Therefore, the full range can be up to 511.9921875 seconds having the required resolution of 0.0078125 seconds.*

2.2.9 ADS-B Report Type Requirements

Equipage classes are defined to accommodate tiered capabilities according to increasingly complex operational objectives while preserving basic inter-operability between classes of equipage. Each equipage class is required to receive messages and process the recovered information into specific ADS-B reports according to the applicable capability. The required ADS-B report capabilities for each class of equipage are specified in the following paragraphs.

2.2.9.1 ADS-B Receiver Reporting Requirements for Class A Equipage

ADS-B Report Requirements for Class A Equipage are specified in Table 2-100. For each required report type all data elements, as defined in §2.2.8.1 through §2.2.8.3 (inclusive of subparagraphs), **shall** be included for which valid information is available (i.e., current information that has been received via one or multiple ADS-B Messages or is available from an onboard data source). Although the Report Assembly Function is required to support all data elements specified for the report types applicable to that Equipage Class, as per Table 2-100, reports may be generated that convey only a subset of the report elements. This is a consequence of certain data elements only being applicable while airborne and others that are only applicable while on the surface. Also the ADS-B Messages may not have been received that included the information necessary to report a valid value for a given report data element. For each of the four types of reports there is a set of required data elements that **shall** be included. The required set of data elements is specified in Table 2-101 through Table 2-104 (inclusive) for the four report types.

The Report Assembly Function **shall** maintain backward compatibility with prior versions of the relevant 1090 MHz ADS-B Messages (i.e., Airborne Position, Surface Position, Airborne Velocity, Aircraft Status, Aircraft Operational Status, and Aircraft Identification and Category) that are used as the basis for generating State Vector, Air Referenced Velocity and Mode Status Reports. The relevant Version Zero (0) message formats, conformant to RTCA DO-260, including Change 1, and the relevant Version

One (1) messages, conformant to RTCA DO-260A, including Change 1 and Change 2, and their required use for ADS-B report generation are defined in Appendix N.

Table 2-100: ADS-B Class A Equipment Reporting Requirements

Equipage Class	**INTERACTIVE AIRCRAFT/VEHICLES OPERATIONAL CAPABILITIES**	
	Airborne	Airport Surface
	ADS-B OUTPUT REPORTS REQUIRED (Note 1)	
AO **Minimum** Aircraft/ Ground Vehicles	SV MS	SV MS
A1S/A1 **Basic** Aircraft and Ground Vehicles	SV MS	SV MS
A2 **Enhanced** Aircraft Only (Note 2)	SV MS TS TC+0	SV MS
A3 **Extended** Aircraft Only (Note 2)	SV MS TS TC+n	SV MS

Notes:

1. *The report structure and contents are specified in §2.2.8.1 through §2.2.8.3, inclusive of the subparagraphs.*

2. *It is anticipated that future revisions of these MOPS will require that Equipage Class A2 and A3 systems will also be capable of generating Trajectory Change Reports.*

Table 2-101: ADS-B State Vector Required Report Elements

Report Element #	Report Element Description	Required
0a, 0b	Report Type and Structure Identification	**Yes**
0c	Validity Flags	**Yes**
1	Participant Address	**Yes**
2	Address Qualifier	**Yes**
3	Time of Applicability (Position and Velocity)	**Yes**
4	Latitude (WGS-84)	Note 3
5	Longitude (WGS-84)	Note 3
6	Altitude, Geometric (WGS-84)	**No**
7	North/South Velocity	Note 3
8	East/West Velocity	Note 3
9	Ground Speed while on the Surface	Note 1
10	Heading while on the Surface	Note 1
11	Altitude, Barometric (Pressure Altitude)	Note 2
12	Vertical Rate, Geometric/Barometric (WGS-84)	**No**
13	Navigation Integrity Category (NIC)	**Yes**
14	Estimated Latitude (WGS-84)	**Yes**
15	Estimated Longitude (WGS-84)	**Yes**
16	Estimated North/South Velocity	Note 2
17	Estimated East/West Velocity	Note 2
18	Surveillance Status/Discretes	**No**
19	Report Mode	**No**

Notes:

1. *Required when the report is for a target Aircraft/Vehicle that is on the airport surface.*
2. *Required when the report is for a target aircraft that is airborne.*
3. *It is required that each new state vector report for an airborne target include report elements 4 and 5 and/or report elements 7 and 8 since a new state vector report should only be generated based on the reception of an Airborne Position and/or an Airborne Velocity Message.*

Table 2-102: ADS-B Mode Status Required Report Elements

Report Element Number	Report Element Description	Required when A/V is on Surface	Required when Aircraft is Airborne
0a, 0b	Report Type and Structure	**Yes**	**Yes**
0c	Validity Flags	**Yes**	**Yes**
1	Participant Address	**Yes**	**Yes**
2	Address Qualifier	**Yes**	**Yes**
3	Time of Applicability	**Yes**	**Yes**
4	ADS-B Version	**Yes**	**Yes**
5a	Call Sign	Note 1	Note 1
5b	Emitter Category	Note 1	Note 1
5c	A/V Length and Width Code	Note 2	**No**
6	Emergency/Priority Status	Note 5	Note 5
7	Capability Codes	Note 3	Note 3
8	Operational Mode	Note 3	Note 3
9a	SV Quality - NACp	Note 3	Note 3
9b	SV Quality - NAC_V	Note 4	Note 4
9c	SV Quality – SIL	Note 3	Note 3
9d	SV Quality – BAQ (reserved)	**No**	**No**
9e	SV Quality – NIC_{BARO}	**No**	Note 3
10a	True/Magnetic Heading	Note 2	Note 2
10b	Vertical Rate Type	Note 4	Note 4
11	Other (Reserved)	**No**	**No**

Notes:

1. *Required if an Aircraft Identification Message has been received within the past 200 seconds.*

2. *Required if an Aircraft Operational Status Message has been received within the past 100 seconds.*

3. *Required if an Aircraft Operational Status and/or a Target State and Status Message has been received within the past 100 seconds.*

4. *Required if an Airborne Velocity Message has been received within the past 100 seconds.*

5. *Required if an Extended Squitter Aircraft Status Message (TYPE=28, Subtype=1) and/or Target State and Status Message (TYPE=29, Subtype=0) has been received within the past 100 seconds.*

Table 2-103: ADS-B Target State Required Report Elements

Report Element Number	Report Element Description	Required
0a, 0b	Report Type and Structure Identification	**Yes**
1	Participant Address	**Yes**
2	Address Qualifier	**Yes**
3	Report Time of Applicability	**Yes**
4a	Horizontal Intent: Horizontal Data Available & Horizontal Target Source Indicator	**Yes**
4b	Horizontal Intent: Target Heading or Track Angle	Note 1
4c	Horizontal Intent: Target Heading/Track Indicator	Note 1
4d	Horizontal Intent: Reserved for Heading/Track Capability	Note 1
4e	Horizontal Intent: Horizontal Mode Indicator	Note 1
4f	Horizontal Intent: Reserved for Horizontal Conformance	**No**
5a	Vertical Intent: Vertical Data Available & Vertical Target Source Indicator	**Yes**
5b	Vertical Intent: Target Altitude	Note 2
5c	Vertical Intent: Target Altitude Type	Note 2
5d	Vertical Intent: Target Altitude Capability	Note 2
5e	Vertical Intent: Vertical Mode Indicator	Note 2
5f	Vertical Intent: Reserved for Vertical Conformance	**No**

Notes:

1. *Required if Report Element 4a indicates that data is available.*

2. *Required if Report Element 5a indicates that data is available.*

Table 2-104: ADS-B Air Referenced Velocity Required Report Elements

Report Element Number	Report Element Description	Required
0a, 0b	Report Type and Structure Identification	**Yes**
0c	Validity Flags	**Yes**
1	Participant Address	**Yes**
2	Address Qualifier	**Yes**
3	Report Time of Applicability	**Yes**
4a	Airspeed	**Yes**
4b	Airspeed Type and Validity	**Yes**
5	Heading While Airborne	**Yes**

2.2.9.1.1 ADS-B State Vector Reports for Class A Equipage

Equipage Class A0, A1S, A1, A2 and A3 equipment **shall** provide State Vector Reports as indicated in §2.2.9.1. An example report format is shown in Table 2-81.

2.2.9.1.2 ADS-B Mode Status Reports for Class A Equipage

Equipage Class A0, A1S, A1, A2 and A3 equipment **shall** provide Mode Status Reports as indicated in §2.2.9.1. An example report format is shown in Table 2-88.

2.2.9.1.3 ADS-B Target State Reports for Class A Equipage

a. Equipage Class A0, A1S and A1 equipment are not required to provide Target State Reports.

b. Equipage Class A2 and A3 equipment **shall** provide Target State Reports as indicated in §2.2.9.1. An example report format is shown in Table 2-94.

c. Target State Reports for newly acquired target aircraft **shall** not be provided until or unless an Aircraft Operational Status Message (§2.2.3.2.7.2) has been received from the target aircraft indicating an ADS-B Version Number of other than Zero (0).

Note: *Version Zero (0) messages that convey trajectory intent information using message TYPE Code 29 (see Appendix N) are not to be used by 1090 MHz ADS-B receiving systems conformant to these MOPS for the purpose of report generation. Therefore a positive determination that the applicable Version Number is other than Zero (0) for a received message with a TYPE Code of 29 is necessary in order to avoid errors in the reporting of the aircraft target state.*

2.2.9.1.4 ADS-B Air Referenced Velocity Reports for Class A Equipage

a. Equipage Class A0 equipment is not required to provide Air Referenced Reports.

b. Equipage Class A1S, A1, A2 and A3 equipment **shall** generate an Air Referenced Velocity Report as indicated in §2.2.9.1. An example report format is shown in Table 2-96.

2.2.9.2 ADS-B Receiver Report Content Requirements for Class B Equipage

There are no report requirements for Class B, i.e., Broadcast Only, Equipage.

2.2.10 ADS-B Receiver Report Assembly and Delivery

Note: *This paragraph and its subparagraphs describe report assembly and delivery only for ADS-B Receiving Subsystems. See §2.2.17.4 and its subparagraphs for requirements on TIS-B report aseembly and delivery.*

2.2.10.1 Fundamental Principals of Report Assembly and Delivery

2.2.10.1.1 General Data Flow

Figure 2-19 illustrates the general data flow of ADS-B Messages and Reports for the purposes of establishing the baseline requirements for Report Assembly and Delivery.

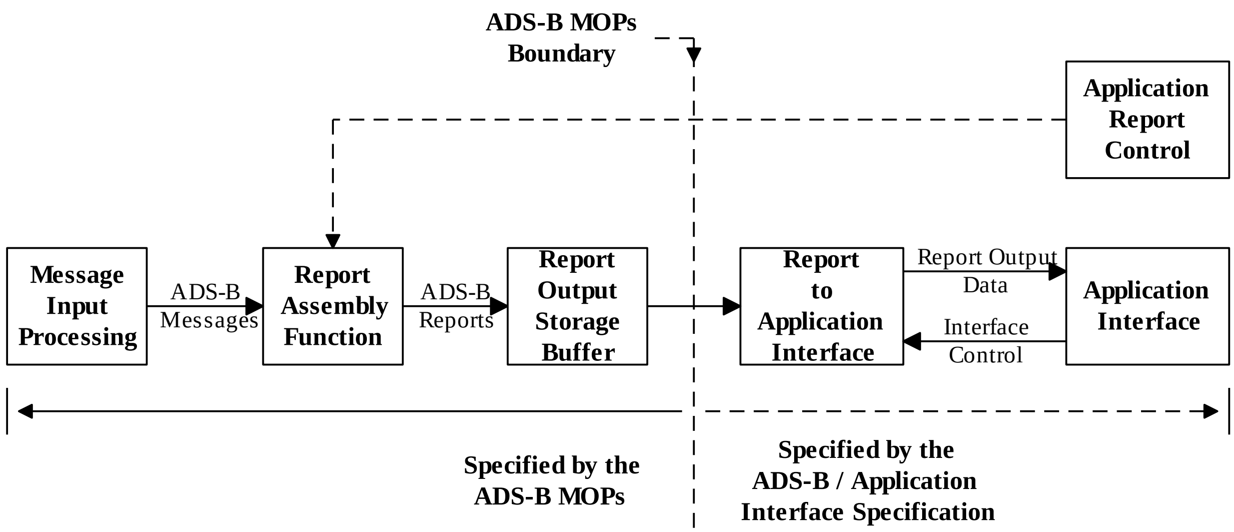


Figure 2-19: ADS-B Message And Report General Data Flow

a. **Message Input Processing** -- The Message Input Processing is performed by the ADS-B Message Reception Function previously depicted in Figure 2-16 and described in §2.2.6.1. The primary function of the Message Input Processing function is to deliver all received ADS-B Messages to the Report Assembly Function.

b. **Report Assembly Function** -- The Report Assembly Function receives all ADS-B Messages from the Message Input Processing Function and structures ADS-B Reports for delivery to the Report Output Storage Buffer.

   It is important to note that the specification of requirements within this document is considered complete once the ADS-B Reports have been structured and delivered to the Report Output Storage Buffer. Specifically, the specification of data delivery via the Application Interface is not addressed in this document. Figure 2-19 illustrates the boundary of the ADS-B MOPS specification.

c. **Report Output Storage Buffer** -- The primary purpose of the Report Output Storage Buffer is to store and maintain all ADS-B reports such that the Reports are available for extraction by the Application Interface upon demand or as needed.

d. **Application Report Control** -- The Application Report Control depicted in Figure 2-19 represents an ***optional*** function that may be implemented for the application to provide commands or control to the Report Assembly Function in order to control the size of various ADS-B reports and/or the conditions under which such reports are issued.

e. **Application Interface** -- The Application Interface is responsible for the extraction of ADS-B reports from the Report Output Storage Buffer via the Report to Application Interface. Requirements for the Application Interface and Report to Application Interface are to be specified in various Application Interface specifications and therefore are not addressed in this document.

Note: *Figure 2-20, Figure 2-21 and Figure 2-22 are provided below as a guideline to assist in understanding the Report Assembly and Delivery Process. As such, these figures should not be construed as presenting the actual requirements. Rather, the requirements for Report Assembly and Delivery are provided in the remaining subparagraphs of §2.2.10.*

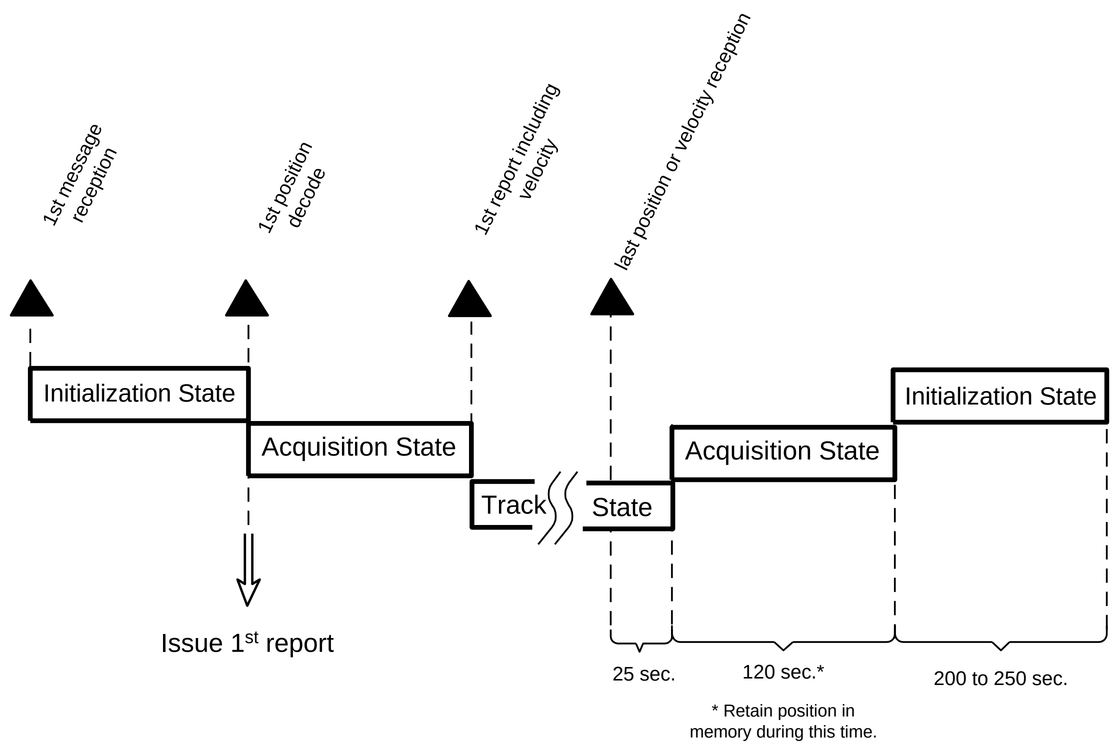
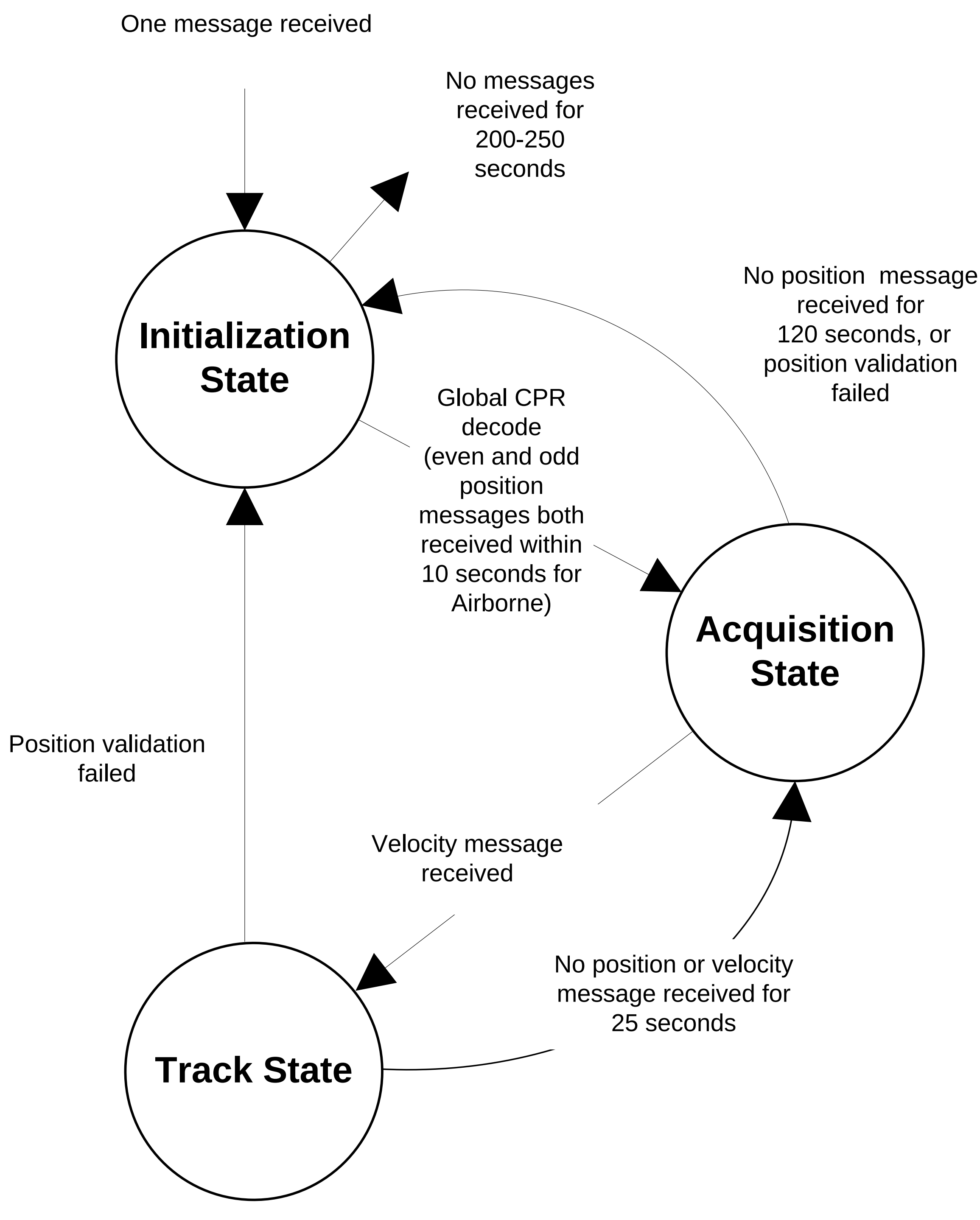


Figure 2-20: Illustration of Report State Changes In A Typical Case



<u>Figure 2-21:</u> Report Assembly Airborne State Transition Diagram

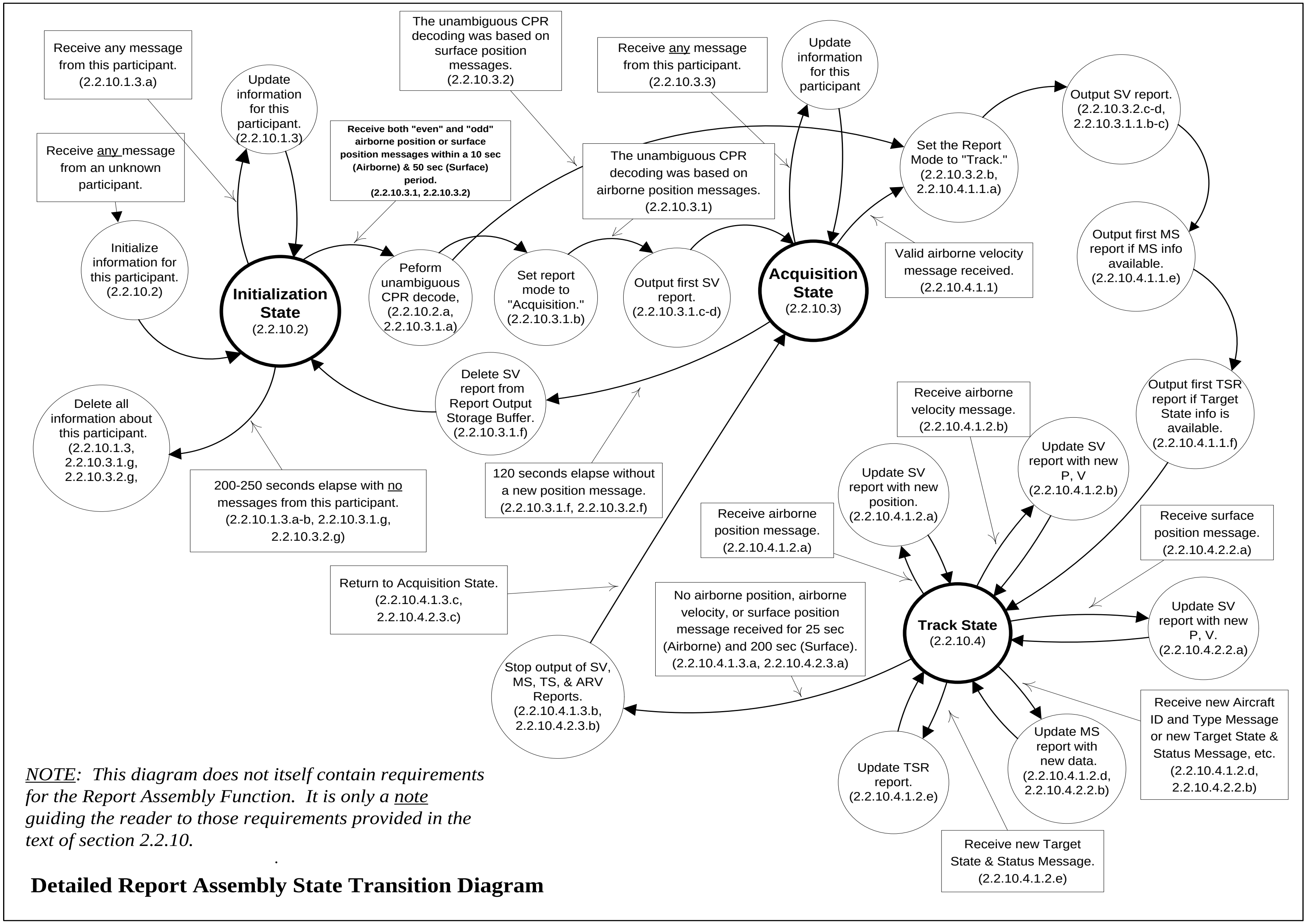


Figure 2-22: Detailed Report Assembly State Transition Diagram

2.2.10.1.2 ADS-B Report Organization

a. All ADS-B Message receptions and Reports **shall** be organized (i.e., indexed) in accordance with the Participant Address (see §2.2.3.2.1.1) and the Address Qualifier (see §2.2.8.1.3).

Note: *The Participant Address, report element 1 in all ADS-B report structures. Is conveyed in the "AA" Address Field of all ADS-B transmitted messages. The Address Qualifier, report element 2 in all the ADS-B report structures, denotes whether the address is a 24-bit ICAO aircraft address or some other kind of address, and is conveyed in the combination of DF fields and, if DF=18, in the CF field in ADS-B transmitted messages.*

b. For the purposes of correlating received ADS-B Messages to existing Reports, separate Reports **shall** be maintained for the same Participant Address (see §2.2.3.2.1.1) and Address Qualifier (see §2.2.8.1.3) if DF=17 ADS-B Messages are received from one aircraft/vehicle and DF=18 Messages from another aircraft/vehicle.

Note: *Duplicate address processing as per §2.2.10.7 helps protect against not detecting an aircraft/vehicle that is transmitting with the same 24-bit address. However, duplicate address processing is not required when addresses can be resolved when one aircraft/vehicle is from a Mode S transponder based transmitting system and the other is from a Non-transponder based transmitting system.*

c. The Participant Address and the Address Qualifier **shall** be required elements in all ADS-B Reports (see Table 2-81 Items 1 and 2, Table 2-88 Items 1 and 2, Table 2-94 Items 1 and 2, and Table 2-96 Items 1 and 2).

2.2.10.1.3 ADS-B Message Temporary Retention

a. Unless otherwise specified, all ADS-B Messages and decoded latitude and longitude values received for a given Participant **shall** be appropriately time tagged and temporarily stored for at least 200 seconds unless replaced by a received message of equivalent type from that Participant.

Note: *This requirement is intended to aid in the start-up of Report Assembly for a given Participant such that as much data as possible can be provided as soon as a Track is initialized on the given participant.*

b. If no new messages have been received from a given Participant for 250 seconds, then all records (including temporary storage) relevant to the Participant Address **shall** be deleted from temporary storage and from the Report Output Storage Buffer.

2.2.10.1.4 Participant ADS-B Track Files

A Track File is defined as the accumulation of reports maintained on a given participant. In the ADS-B case, the Track File refers to the State Vector, Mode Status, Target State and Air Referenced Velocity Reports, which comprise a set of reports maintained on a given participant.

The ADS-B Report Assembly function **shall** maintain one, and only one, Track File, i.e., set of reports on any given participant.

2.2.10.2 Report Assembly Initialization State

The Initialization State is entered for any given Participant for which there is no information upon receipt of any of the following ADS-B Messages received from the given Participant:

a. Airborne Position Message (i.e., a State Vector Position Message --- Airborne) (see §2.2.3.2.3)

b. Surface Position Message (i.e., a State Vector Position Message --- Surface) (see §2.2.3.2.4)

c. ADS-B Aircraft Identification and Category Message (see §2.2.3.2.5)

d. ADS-B Airborne Velocity Message (see §2.2.3.2.6)

e. Target State and Status Message (see §2.2.3.2.7.1)

f. "Aircraft" Operational Status Message (see §2.2.3.2.7.2)

Note: *Upon the first receptions of airborne-format messages from a target that is already in the Track State as a Surface Participant, it is not necessary to enter the Initialization State or the Acquisition State. The target remains in the Track State, now as an Airborne Participant. Similarly, for the transition from airborne-format to surface-format messages, if the target is currently in the Track State, it remains in the Track State, now as a Surface Participant.*

2.2.10.3 Report Assembly Acquisition State

2.2.10.3.1 Report Assembly Acquisition State --- Airborne Participant

Upon receipt of an ***"even"*** and an ***"odd"*** encoded Airborne Position Message from a given Participant within a ten second period, the Report Assembly Function **shall**:

a. Perform a successful Globally Unambiguous CPR decode of the Participant Position in accordance with §A.1.7.7 of Appendix A. Perform a validation of the resulting position decode as follows: Compute the distance between own receiver position, if known, and the Participant Position resulting from the Globally Unambiguous CPR decode. The position validation is failed if the computed distance is greater than the maximum operating range of the receiver. If position validation is not failed, then proceed with subparagraph "b" below. Otherwise, discard the "***even***" and "***odd***" Position Messages used in the attempted Globally Unambiguous CPR decode. The Report Mode for the given Airborne Participant remains in Initialization State.

   Note: *If the Airborne Participant has already been in the Track State as a Surface Participant, then it is not necessary to perform the Globally Unambiguous CPR Decode.*

b. Set the Report Mode to "Acquisition" for the given Airborne Participant in the State Vector Report (see §2.2.8.1) in accordance with §2.2.8.1.22,

c. Structure all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive),

d. Deliver the first structured State Vector Report for the given Airborne Participant to the Report Output Storage Buffer for subsequent access by the Application Interface on demand,

e. Continue to maintain the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for at least 200 seconds unless replaced by an updated State Vector Report or otherwise specified in the following sections, the conditions of the following subparagraphs **shall** apply:

f. If a new Position Message is not received within a 120 second period, then the Globally Unambiguous CPR decode performed in step a. **shall** be considered to be invalid, and the Report Assembly Function **shall** return to the Initialization State. (In order to proceed to the Track State for the airborne participant, the Globally Unambiguous CPR decode will need to be repeated.)

Note: *This action effectively represents a return to the Initialization State with the exception that the return is to step a. above, and the report is retained as per step e. The purpose of this action is to minimize the need to perform the Globally Unambiguous CPR decode since it is not necessary when position messages have been received within the reasonable time limit of 120 seconds. This action is illustrated in Figure 2-21.*

g. If no new messages have been received from a given Airborne Participant for at least 200 seconds, then all reports relevant to the Participant Address **shall** be deleted from the Report Output Storage Buffer.

2.2.10.3.1.1 Latency, Report Assembly Acquisition State --- Airborne Participant

Step 2.2.10.3.1.d **shall** be completed within 500 milliseconds of receipt of the second Airborne Position Message of the "***even***" and "***odd***" pair.

2.2.10.3.2 Report Assembly Acquisition State --- Surface Participant

Upon receipt of an ***"even"*** and an ***"odd"*** encoded Surface Position Message from a given Participant within a time period of interval "**X**" (where **X**=50 seconds, unless the Ground Speed in either Surface Position Message is greater than 25 knots, or is unknown, in which cases **X**=25 seconds), the Report Assembly Function **shall**:

a. Perform a successful Globally Unambiguous CPR decode of the Participant Position in accordance with §A.1.7.8 of Appendix A. Perform a validation of the resulting position decode as follows: Compute the distance between own aircraft position, if known, and the Participant Position resulting from the Globally Unambiguous CPR decode. The position validation is failed if the computed distance is greater than the maximum operating range of the receiver. If position validation is not failed, then proceed with subparagraph "b" below. Otherwise, discard the "***even***" and "***odd***" Position Messages used in the attempted Globally Unambiguous CPR decode. The Report Mode for the given Surface Participant remains in Initialization State.

Note: *If the Surface Participant has already been in the Track State as an Airborne Participant, then it is not necessary to perform the Globally Unambiguous CPR Decode.*

b. Set the Report Mode to "Track" for the given Surface Participant in the State Vector Report (see §2.2.8.1) in accordance with §2.2.8.1.22,

c. Structure all possible fields of the State Vector Report for the given Surface Participant in accordance with §2.2.8.1 (all subsections inclusive),

d. Deliver the first structured State Vector Report for the given Surface Participant to the Report Output Storage Buffer for subsequent access by the Application Interface on demand,

e. Continue to maintain the integrity of the State Vector Report for the given Surface Participant in the Report Output Storage Buffer for at least 200 seconds unless replaced by an updated State Vector Report or otherwise specified in the following sections, and the conditions of the following subparagraphs **shall** apply:

f. If a new Position Message is not received within a 120 second period, then the Globally Unambiguous CPR decode performed in Step "a" **shall** be considered to be invalid, and the Report Assembly Function **shall** return to the Initialization State. In order to proceed from the Acquisition State to the Track State, the Globally Unambiguous CPR decode must be repeated.

Note: *This action effectively represents a return to the Initialization State with the exception that the return is to Step "a" above, and the report is retained as per Step "e." The purpose of this action is to minimize the need to perform the Globally Unambiguous CPR decode since it is not necessary when position messages have been received within the reasonable time limit of 120 seconds. This action is illustrated in Figure 2-21.*

g. If no new messages have been received from a given Surface Participant for at least 200 seconds, then all reports relevant to the Participant Address **shall** be deleted from the Report Output Storage Buffer.

2.2.10.3.2.1 Latency, Report Assembly Acquisition State --- Surface Participant

Step 2.2.10.3.2.d **shall** be completed within 500 milliseconds of receipt of the second Surface Position Message of the "***even***" and "***odd***" pair.

2.2.10.3.3 Acquisition State Data Retention

Upon receipt of any of the messages identified in §2.2.10.2 for any given participant, the received message **shall** either:

a. Use the message as required in §2.2.10.3.1 for Airborne Participants or §2.2.10.3.2 for Surface Participants, or

b. Retain the message for future use as specified in §2.2.10.1.3.

2.2.10.4 Report Assembly Track State

2.2.10.4.1 Report Assembly Track State --- Airborne Participant

2.2.10.4.1.1 Report Assembly Track State Initialization --- Airborne Participant

Initialization of the Track State for a given Airborne Participant assumes that the Acquisition State has been established for the given Participant in accordance with §2.2.10.3.1.

Upon receipt of a valid Airborne Velocity Message (see §2.2.3.2.6) for a given Airborne Participant, the Report Assembly Function **shall**:

a. Set the Report Mode to “Track” for the given Airborne Participant in the State Vector Report (see §2.2.8.1) in accordance with §2.2.8.1.22,

b. Structure all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive),

c. Deliver the new State Vector Report for the given Airborne Participant to the Report Output Storage Buffer within 500 milliseconds of receipt of the Airborne Velocity Message,

d. Maintain the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated State Vector Report or otherwise specified in the following sections,

e. <u>Initiate Assembly of Mode Status Reports</u>:

   (1). The Report Assembly Function **shall** review all messages received from the given Airborne Participant that may have been placed in temporary storage in accordance with §2.2.10.1.3.

   (2). Upon completion of the message review, the Report Assembly Function **shall** structure all possible fields of the Mode Status Report for the given Airborne Participant in accordance with §2.2.8.2 (all subsections inclusive).

   (3). The Report Assembly Function **shall** deliver the new Mode Status Report for the given Airborne Participant to the Report Output Storage Buffer within 500 milliseconds of receipt of the Airborne Velocity Message which initialized the Track State.

   (4). The Report Assembly Function **shall** maintain the integrity of the Mode Status Report for the given Airborne Participant in the Report Output Storage Buffer 100 ±5 seconds unless replaced by an updated Mode Status Report or otherwise specified in the following sections.

f. <u>Initiate Assembly of ADS-B Target State Reports:</u>

   (1). The Report Assembly Function **shall** review all messages received from the given Airborne Participant that may have been placed in temporary storage in accordance with §2.2.10.1.3.

(2). Upon completion of the message review, the Report Assembly Function **shall** structure all possible fields of the ADS-B Target State Report for the given Airborne Participant in accordance with §2.2.8.3 (all subsections inclusive).

(3). The Report Assembly Function **shall** deliver the new ADS-B Target State Report for the given Airborne Participant to the Report Output Storage Buffer within 500 milliseconds of receipt of the Airborne Velocity Message which initialized the Track State.

(4). The Report Assembly Function **shall** maintain the integrity of the ADS-B Target State Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated ADS-B Target State Report or otherwise specified in the following sections.

2.2.10.4.1.2 Report Assembly Track State Maintenance --- Airborne Participant

The Track State **shall** be maintained for a given Airborne Participant for as long as Airborne Position Messages (see §2.2.3.2.3) and Airborne Velocity Messages (see §2.2.3.2.6) are being received from the Participant.

a. Each time that a new Airborne Position Message is received from the given Airborne Participant, the Report Assembly Function **shall**:

(1). Perform a Local CPR decode of the Airborne Participant Position in accordance with §A.1.7.4 and §A.1.7.5 of Appendix A. Perform the reasonableness test identified in §2.2.10.6.3 to verify that the most recently received position does not represent an unreasonable offset from the previous aircraft position.

A. If the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the position decodes resulting from the reasonableness test of §2.2.10.6.3 are less than or equal to 6 NM if the last Position Message received was an Airborne Position Message, or less than or equal to 2.5 NM if the last Position Message received as a Surface Position Message, then the validation is successful and complete, and the position can be used to update the track.

B. If the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the reported position in the most recently received Position Message differs from the previously reported position by more than 6 NM if the last Position Message received was an Airborne Position Message, or more than 2.5 NM if the last Position Message received as a Surface Position Message, then the most recently received position **shall not** be used to update the track.

(2). Update all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive),

(3). Deliver the updated State Vector Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new Airborne Position Message, and

(4). Maintain the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated State Vector Report or otherwise specified in the following sections.

b. Each time that a new Airborne Velocity Message is received from the Airborne Participant that contains Ground Referenced Velocity information, the Report Assembly Function **shall**:

(1). Update all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive),

(2). Deliver the updated State Vector Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new Airborne Position Message, and

(3). Maintain the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated State Vector Report or otherwise specified in the following sections.

c. Each time an ADS-B Airborne Velocity Message (§2.2.3.2.6) with Subtype="3" or "4" (i.e., providing Air Referenced Velocity information) is received from the ADS-B Airborne Participant, then the Report Assembly Function **shall**:

(1). Update all possible fields of the Air Referenced Velocity Report for the given ADS-B Airborne Participant in accordance with §2.2.8.3.2 (all subsections inclusive),

(2). Deliver the updated ARV Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new ADS-B Airborne Velocity Message, and

(3). Maintain the integrity of the ARV Report for the given ADS-B Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated ARV Report or otherwise specified in the following sections.

d. Each time that a new Aircraft Identification and Category Message (see §2.2.3.2.5), Target State and Status Message (see §2.2.3.2.7.1) having system status information, Aircraft Operational Status Message (see §2.2.3.2.7.2), Airborne Velocity Message (§2.2.3.2.6), or Extended Squitter Aircraft Status Message (see §2.2.3.2.7.8) is received from the Airborne Participant, the Report Assembly Function **shall**:

(1). Update all possible fields of the Mode Status Report for the given Airborne Participant in accordance with §2.2.8.2 (all subsections inclusive),

(2). Deliver the updated Mode Status Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new Message, and

(3). Maintain the integrity of the Mode Status Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated Mode Status Report or otherwise specified in the following sections.

e. Each time that a new Target State and Status Message (see §2.2.3.2.7.1) having Target State information is received from the given Airborne Participant, the Report Assembly Function **shall**:

(1). Update all possible fields of the ADS-B Target State Report for the given Airborne Participant in accordance with §2.2.8.3 (all subsections inclusive),

(2). Deliver the updated ADS-B Target State Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new Message, and

(3). Maintain the integrity of the ADS-B Target State Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated ADS-B Target State Report or otherwise specified in the following sections.

2.2.10.4.1.3 Report Assembly Track State Termination --- Airborne Participant

a. The Track State **shall** be terminated for a given Airborne Participant if no Airborne Position (see §2.2.3.2.3) or Airborne Velocity Messages (see §2.2.3.2.6) have been received from the Participant in 25 ±5 seconds.

b. Upon termination of the Track State for a given Airborne Participant, the Report Assembly Function **shall** immediately delete all State Vector, Mode Status, ADS-B Target State, and Air Referenced Velocity Reports that were placed in the Report Output Storage Buffer for the given Participant.

Note: *The track state termination requires deletion of all reports structured for a given participant into the Report Output Storage Buffer. Track state termination does not intend that temporary storage (see §2.2.10.1.3) established for the given Participant be deleted. The temporary storage is only deleted if NO ADS-B Messages have been received from the given Participant for 225 ±25 seconds.*

c. Upon completion of the preceding step b., the Report Assembly Function **shall** return to the Report Assembly Acquisition State for the given Airborne Participant as specified in §2.2.10.3.1.

2.2.10.4.2 Report Assembly Track State --- Surface Participant

2.2.10.4.2.1 Report Assembly Track State Initialization --- Surface Participant

Initialization of the Track State for a given Surface Participant is established in accordance with §2.2.10.3.2.

In addition to the requirements specified in §2.2.10.3.2, the Report Assembly Function **shall** initiate assembly of Mode Status Reports as follows:

a. The Report Assembly Function **shall** review all messages received from the given Surface Participant that may have been placed in temporary storage in accordance with §2.2.10.1.3.

b. Upon completion of the message review, the Report Assembly Function **shall** structure all possible fields of the Mode Status Report for the given Surface Participant in accordance with §2.2.8.2 (all subsections inclusive).

c. The Report Assembly Function **shall** deliver the new Mode Status Report for the given Surface Participant to the Report Output Storage Buffer within 500 milliseconds of receipt of the last received Surface Position Message that initialized the Track State.

d. The Report Assembly Function **shall** maintain the integrity of the Mode Status Report for the given Surface Participant in the Report Output Storage Buffer 100 ±5 seconds unless replaced by an updated Mode Status Report or otherwise specified in the following sections.

2.2.10.4.2.2 Report Assembly Track State Maintenance --- Surface Participant

The Track State **shall** be maintained for a given Surface Participant for as long as Surface Position Messages (see §2.2.3.2.4) are being received from the Surface Participant.

a. Each time that a new Surface Position Message is received from the given Surface Participant, the Report Assembly Function **shall**:

(1). Perform a Local CPR decode of the Surface Participant Position in accordance with §A.1.7.4 and §A.1.7.6 of Appendix A. Perform the reasonableness test identified in §2.2.10.6.3 to verify that the most recently received position does not represent an unreasonable offset from the previous aircraft position.

A. If the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the position decodes resulting from the reasonableness test of §2.2.10.6.3 are less than or equal to 0.75 NM if the last Position Message received was a Surface Position Message, or less than or equal to 2.5 NM if the last Position Message received was an Airborne Position Message, then the validation is successful and complete, and the position can be used to update the track.

B. If the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the reported position in the most recently received Position Message differs from the previously reported position by more than 0.75 NM if the last Position Message received was a Surface Position Message, or more than 2.5 NM if the last Position Message received was an Airborne Position Message, then the most recently received position **shall not** be used to update the track.

(2). Update all possible fields of the State Vector Report for the given Surface Participant in accordance with §2.2.8.1 (all subsections inclusive),

(3). Deliver the updated State Vector Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new Surface Position Message, and

(4). Maintain the integrity of the State Vector Report for the given Surface Participant in the Report Output Storage Buffer for 200 ±5 seconds unless replaced by an updated State Vector Report or otherwise specified in the following sections.

b. Each time that a new Aircraft Identification and Category Message (see §2.2.3.2.5), Aircraft Operational Status Message (see §2.2.3.2.7.2), or Aircraft Status Message (see §2.2.3.2.7.8) is received from the Surface Participant, the Report Assembly Function **shall**:

(1). Update all possible fields of the Mode Status Report for the given Surface Participant in accordance with §2.2.8.2 (all subsections inclusive),

(2). Deliver the updated Mode Status Report to the Report Output Storage Buffer within 500 milliseconds of receipt of the new Message, and

(3). Maintain the integrity of the Mode Status Report for the given Surface Participant in the Report Output Storage Buffer for 200 ±5 seconds unless replaced by an updated Mode Status Report or otherwise specified in the following sections.

2.2.10.4.2.3 Report Assembly Track State Termination --- Surface Participant

a. The Track State **shall** be terminated for a given Surface Participant if no Surface Position Message (see §2.2.3.2.4) has been received from the Participant in 200 ±5 seconds.

b. Upon termination of the Track State for a given Surface Participant, the Report Assembly Function **shall** immediately delete all State Vector and Mode Status Reports that were placed in the Report Output Storage Buffer for the given Participant.

Notes:

1. *The track state termination requires deletion of all reports structured into the Report Output Storage Buffer. Track state termination does not intend that temporary storage (see §2.2.10.1.3) established for the given Participant be deleted. The temporary storage is only deleted if NO ADS-B Messages have been received from the given Participant for 225 ±25 seconds.*

2. *ADS-B Surface Participants do not generate Trajectory Intent information; therefore, ADS-B Target State Report assembly is not required for Surface Participants.*

c. Upon completion of the preceding step b., the Report Assembly Function **shall** return to the Report Assembly Acquisition State for the given Surface Participant as specified in §2.2.10.3.2.

2.2.10.5 Minimum Number of Participant Track Files

In the absence of an applied interference environment and other interference, the ADS-B Report Assembly Function **shall** be capable of:

a. Maintaining the minimum number of track files (see §2.2.10.1.4) of any mix of ADS-B Participants and TIS-B targets as specified in Table 2-105 for a given equipage class, and

Table 2-105: Minimum Participant Track File Capacity

Equipage Class of ADS-B Receiving Subsystem	Minimum Number of Participant Track Files
A0	100
A1S/A1	200
A2	400
A3	400

b. If the track file capacity of the ADS-B Receiving Subsystem is being exceeded by the number of participants whose messages are being received by the subsystem, then the subsystem may choose to discard track files of those participants that are not of operational interest to the Receiving Subsystem (e.g., range and/or altitude filtering).

2.2.10.6 Reasonableness Tests for CPR Decoding of Received Position Messages

2.2.10.6.1 Reasonableness Test Overview

Although receptions of Position Messages will normally lead to a successful target position determination, it is necessary to safeguard against Position Messages that would be used to initiate or update a track with an erroneous position. A reasonableness test applied to the computed position resulting from receipt of a Position Message can be used to discard erroneous position updates. Since an erroneous Globally Unambiguous CPR Decode could potentially exist for the life of a track, a reasonableness test and validation of the position protects against such occurrences. Likewise, an erroneous Locally Unambiguous CPR Decode could result in an incorrect position that potentially remains incorrect for the life of the track.

2.2.10.6.2 Reasonableness Test Applied to Positions Determined from Globally Unambiguous CPR Decoding

A validation **shall** be performed to verify the Globally Unambiguous CPR decode established per §2.2.10.3.1, subparagraph "a" or §2.2.10.3.2, subparagraph "a," using the following steps:

a. Compute a second Globally Unambiguous CPR decode based on reception of a new "***odd***" and an "***even***" Position Message as per §2.2.10.3.1, subparagraph "a" for an Airborne Participant, or per §2.2.10.3.2, subparagraph "a" for a Surface Participant, both received subsequent to the respective "***odd***" and "***even***" Position Message used in the Globally Unambiguous CPR decode under validation.

b. Compare the position decode resulting from the Globally Unambiguous CPR decode as per subparagraph "a" above to the Locally Unambiguous CPR decode computed from the receipt of the current Position Message satisfying subparagraph "a" above,

<u>Note:</u> *The Locally Unambiguous CPR decode is based on the update of the position derived from the current Globally Unambiguous CPR decode established in §2.2.10.3.1, subparagraph "a," or §2.2.10.3.2, subparagraph "a."*

c. If the position decodes resulting from subparagraph "b" above are identical to within 5 meters for an airborne decode and 1.25 meters for a surface decode, then the validation is complete. Otherwise, the following subparagraph applies:

d. No State Vector Report is generated from the receipt of the current Position Message. The Report Mode for the given Participant Report Mode is reset to the Initialization State. All "***even***" and "***odd***" Position Messages received prior to the respective "***even***" or "***odd***" Position Message used in the Globally Unambiguous CPR decode in subparagraph "a" above are discarded.

Note: *Completion of validation requires reception of both an additional "even" and "odd" Position Message subsequent to the Position Messages used to satisfy the Globally Unambiguous CPR decode in Acquisition State. In the case of Airborne Participants, since reception of an Airborne Velocity Message causes a transition from Acquisition State to Track State, as per §2.2.10.4.1.1, then validation may not be completed until the Airborne Participant is in the Track State.*

2.2.10.6.3 Reasonableness Test Applied to Positions Determined from Locally Unambiguous CPR Decoding

A validation **shall** be performed to verify the Locally Unambiguous CPR decode established per §2.2.10.4.1.2, subparagraph "a.(1)" for Airborne Participants, or §2.2.10.4.2.2, subparagraph "a.(1)" for Surface Participants, using the following steps:

a. Compare the Locally Unambiguous CPR decode computed from the reception of a new "***odd***" or "***even***" Position Message as per §2.2.10.4.1.2, subparagraph "a.(1)" for an Airborne Participant, or per §2.2.10.4.2.2, subparagraph "a.(1)" for a Surface Participant, to the current position that was computed from the previously received Position Message.

b. If the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the difference in the position decodes resulting from subparagraph "a" above are less than or equal to **X** NM

where:
X=6 for Airborne Participants receiving Airborne Position Messages, or
X=2.5 for Airborne Participants that have received a Surface Position Message, or
X=2.5 for Surface Participants that have received an Airborne Position Message, or
X=0.75 for Surface Participants receiving Surface Position Messages,

then the validation is successful and complete, and the position **shall** be used to update the track. Otherwise, the validation is considered failed, and:

1) the most recently received position **shall not** be used to update the track, and

2) the received position **shall** be used to initiate or update a candidate duplicate address track or update a duplicate address track in accordance with §2.2.10.7.

Notes:

1. *If no duplicate address or candidate duplicate address Report exists for this ICAO 24-bit address, the position message is used to initiate a candidate duplicate address Report. If a candidate duplicate address Report exists, the position message is used to update the candidate duplicate address Report. Otherwise, the position message is used to update the duplicate address Report unless the position message fails this validation test (see §2.2.10.7).*

2. *The position threshold value is based on the assumption of a maximum aircraft velocity of* ***V*** *knots (where* ***V****=600 for Airborne and* ***V****=50 for Surface) over a maximum time period of 30 seconds. This yields a maximum positional difference of approximately 5 NM for Airborne, and 0.5 NM for Surface. An additional measure of 1 nautical mile for Airborne, and 0.25 for Surface are added to account for additional ADS-B positional measurement uncertainty. The position threshold of 2.5 nautical miles between surface and airborne participants was derived from the assumption of 250 knots maximum speed for a target transitioning from the surface state to an airborne state over 30 seconds, yielding approximately 2 nautical miles, with an additional 0.5 NM being added to allow for positional errors.*

2.2.10.7 Duplicate Address Processing

The ICAO 24-bit address transmitted in each ADS-B Message and the derived Address Qualifier is used to identify and associate the messages for a particular aircraft/vehicle. Though each aircraft/vehicle should have a unique ICAO 24-bit address, there may be occasions on which more than one aircraft/vehicle is transmitting the same ICAO 24 bit address. It is important for ADS-B applications that receive 1090ES ADS-B Reports to have knowledge of aircraft within receiving range. The requirements in the following subparagraphs enable detection of a duplicate address aircraft/vehicle when horizontal position separation is outside of the local CPR reasonableness test criteria of §2.2.10.6.3.

Notes:

1. *Without duplicate address detection, an aircraft/vehicle that enters the range of the receiver with the same ICAO 24-bit address as that of an existing ADS-B Report would go undetected and message data from the undetected aircraft/vehicle could be erroneously associated with the existing ADS-B Report.*

2. *Duplicate Address processing is not required for TIS-B targets. The assumption is that the ADS-B Ground Stations will protect against any Duplicate Address situation.*

2.2.10.7.1 Candidate Duplicate Address Report

A candidate duplicate address Report **shall** be initiated when a position message is received for a ICAO 24-bit address that fails the local CPR reasonableness test validation of §2.2.10.6.3.b and no candidate duplicate address Report or duplicate address Report is currently active for the received ICAO 24-bit address. If initiated, the candidate duplicate address Report is set to Initialization State as per §2.2.10.2 and the position message is stored for this candidate duplicate address Report. The ADS-B Report for which the position message did not pass the validation test of §2.2.10.6.3.b, the local

CPR reasonableness test, is the primary ADS-B Report for this ICAO 24-bit address. Once a candidate duplicate address Report is initiated, association of subsequent position messages with this ICAO 24-bit address **shall** be first attempted on the primary ADS-B Report for this ICAO 24-bit address. If the position message does not pass the validation test of §2.2.10.6.3.b on the primary ADS-B Report, the position message **shall** be used to attempt Track Initialization on the candidate duplicate address Report as per §2.2.10.2.

Notes:

1. *TIS-B Reports and ADS-R Reports are separate and distinct from ADS-B Reports as per §2.2.17 and §2.2.18 so there is no duplicate address issues between these Report types and ADS-B Reports.*

2. *Inter-source correlation is addressed in RTCA DO-317.*

2.2.10.7.2 Duplicate Address Condition

A duplicate address condition **shall** be declared for a ICAO 24-bit address when a global CPR decode is completed by the receipt of both an even and odd position message within 10 seconds for the candidate duplicate address and passes the global CPR reasonableness test. Once declared, a duplicate address condition **shall** result in the Duplicate Address Flag in the State Vector Report set to "ON" in the ADS-B Report upon output of either ADS-B Report in the duplicate address condition. ADS-B Position Messages **shall** be associated with the ADS-B Report in the duplicate address condition that passes the local CPR reasonableness test in §2.2.10.6.3.b. Each ADS-B Report in the duplicate address condition **shall** be updated upon receipt of other Extended Squitter Messages containing the duplicate ICAO 24-bit address since there is no means to associate these messages with the correct aircraft.

ADS-B Position, Velocity, Aircraft Identification and Category and Emergency / Priority Status (Subtype=1) Messages from aircraft/vehicles with ICAO 24-bit addresses identified as Duplicate Addresses **shall** be processed as Version ZERO (0) format Messages. Since Target State and Status Messages can be associated with the appropriate MOPS Version Number based on the Subtype and Operational Status Messages contain the MOPS Version Number, these messages can be decoded directly.

Notes:

1. *The Duplicate Address Flag is used to indicate to ADS-B applications that information associated with that address can not be correctly associated with either ADS-B Report in the duplicate address condition. Additionally, the correct MOPS Version Number for each of the aircraft/vehicles can not be readily determined so interpretation of message data defaults to Version ZERO (0).*

2. *The update and output of both ADS-B Reports when Extended Squitter Messages are received with the duplicate ICAO 24-bit address results in additional overhead since output of both ADS-B Reports possibly occurs upon message reception. However, this approach gives ADS-B applications the ability to associate information with the correct ADS-B Report if they choose to attempt to correlate using the additional provided information.*

The duplicate address condition **shall** be cleared after 60 seconds has elapsed with no Position Message update for a Participant with an ADS-B Report identified in the duplicate address condition. The relevant ADS-B Report for the Participant **shall** be deleted from the Report Output Storage Buffer. Output of the remaining ADS-B Report **shall** contain a State Vector Report with the Duplicate Address Flag set to "OFF".

Note: *After clearing the duplicate address condition, the ADS-B Report for the aircraft/vehicle that continues to receive Position Messages that pass the local CPR reasonableness test, as well as other 1090ES ADS-B Messages, is retained and updated as per §2.2.10.4.*

2.2.11 Self Test and Monitors

2.2.11.1 Self Test

If a self-test feature or monitor is provided as part of the equipment:

a. The device which radiates test ADS-B Messages or prevents messages from being broadcast during the test period **shall** be limited to no longer than that required to determine the status of the system.

b. The self-test message signal level at the antenna end of the transmission line **shall** not exceed -40 dBm.

c. If provision is made for automatic periodic self-test procedure, such self-testing **shall** not radiate ADS-B Messages at an average rate exceeding one broadcast every ten seconds.

2.2.11.2 Broadcast Monitoring

2.2.11.2.1 Transponder-Based Equipment

If the ADS-B Transmitting Subsystem is implemented as part of a Mode S Transponder, then the squitter monitor required by RTCA DO-181D, §2.2.10.2 (EUROCAE ED-73C, §3.14.2) is sufficient to ensure proper operation of the transmit chain. If the squitter monitor indicates a failure, the device failure indication **shall** be asserted.

2.2.11.2.2 Non-Transponder-Based Equipment

If the ADS-B Transmitting Subsystem is a broadcast only device, then a monitor **shall** be provided to verify that DF=18 transmissions are generated at the applicable rates specified in §2.2.3.3 through §2.2.3.3.1.3. Event-Driven Squitter rates are not required to be monitored to meet this requirement. If the DF=18 transmissions cannot be transmitted properly, the device failure indication **shall** be asserted (see §2.2.11.5.1).

2.2.11.3 Address Verification

2.2.11.3.1 Transponder-Based Equipment

Transponder implemented ADS-B Transmitting Subsystems **shall** declare a device failure in the event that it's own ICAO 24-bit Address (i.e., the Mode-S Address) is set to all "ZEROs" or all "ONEs."

2.2.11.3.2 Non-Transponder-Based Equipment

Non-transponder implemented ADS-B Transmitting Subsystems **shall** declare a device failure in the event that it's own ICAO 24-bit Address is set to all "ZEROs" or all "ONEs."

2.2.11.4 Receiver Self Test Capability

ADS-B Receiving Devices **shall** be designed to provide sufficient self-test capability to detect a loss of capability to receive ADS-B Messages, structure appropriate ADS-B reports, and make such reports available to the intended user interface. Should the receiving device detect that these basic functions cannot be performed properly, the unit **shall declare a device failure**. Loss of data on external interfaces should not cause the Receiver Device Failure to be asserted.

2.2.11.5 Device Failure Annunciation

2.2.11.5.1 ADS-B Transmission Device Failure Annunciation

An output **shall** be provided to indicate the validity/non-validity of the ADS-B Transmitting Subsystem hardware. Failure to correctly transmit ADS-B Messages detected by self-test, or the broadcast monitoring function, or the address verification **shall** cause the output to assert the FAIL state. Momentary power interrupts **shall** not cause the output to assert the FAIL state. Loss of data on external interfaces should not cause the Transmit Device Failure to be asserted. The status of the ADS-B Transmitting Subsystem **shall** be enunciated to the flight crew where applicable. When the ADS-B Transmit Subsystem is integrated with a Mode S Transponder, the Transponder Fail signal may be used to indicate ADS-B Transmission Device Failure (refer to DO-181D §2.2.10.4, EURCAE ED-73C, §3.14.3).

2.2.11.5.2 ADS-B Receiving Device Failure Annunciation

An output **shall** be provided to indicate the validity/non-validity of the ADS-B receiving device. Failure to accept ADS-B Messages, structure appropriate ADS-B reports, make such reports available to the intended user interface, or failure detected by self-test or monitoring functions **shall** cause the output to assume the invalid state. Loss of data on external interfaces should not cause the Receiver Device Failure to be asserted. Momentary power interrupts **shall** not cause the output to assume the invalid state. The status of the ADS-B receiving device **shall** be enunciated to the flight crew where applicable.

2.2.11.6 ADS-B Function Fail Annunciation

The ADS-B Transmitting and Receiving Subsystems depend on a position source to provide the data to populate the ADS-B Messages and Reports. These sources or interconnects between them and the ADS-B device may fail and prevent the system from transmitting ADS-B Messages or Reports. In this case, the ADS-B transmit/receive subsystem cannot function, but there is not a failure of the ADS-B device itself. It is desirable to indicate that the ADS-B function is failed independently of the ADS-B Device Failure Annunciation.

If the conditions of setting TYPE Code equal ZERO, as per §2.2.3.2.3.1.3.2 are met, then the ADS-B Function Fail Annunciation **shall** be asserted. The status of the ADS-B Function **shall** be indicated to the flight crew.

Note: *Although it is desirable to have an independent ADS-B Function Fail annunciation, some legacy airplanes may have to share the ADS-B Device Failure annunciation to also indicate when an ADS-B Function Fail has occurred. In the case where the ADS-B Transmitting Subsystem is also integrated with a Mode S Transponder (§2.2.11.5.1), caution should be taken to ensure that the ADS-B Function Fail is not interpreted as a Mode S Transponder Device Failure that could generate a subsequent TCAS Fail annunciation.*

2.2.12 Response to Mutual Suppression Pulses

Mutual suppression systems may be needed if the aircraft has other pulse L-band (also known as D-band) equipment on board or if the ADS-B equipment is used in conjunction with certain Collision Avoidance System equipment.

2.2.12.1 ADS-B Transmitting Subsystem Response to Mutual Suppression Pulses

If the ADS-B transmitting equipment is designed to accept and respond to mutual suppression pulses from other electronic equipment in the aircraft (to disable the equipment while the other equipment is transmitting), the equipment **shall** regain normal transmission capability not later than 15 microseconds after the end of the applied mutual suppression pulse.

2.2.12.2 ADS-B Receiving Device Response to Mutual Suppression Pulses

If the ADS-B receiving equipment is designed to accept and respond to mutual suppression pulses from other electronic equipment in the aircraft (to disable the equipment while the other equipment is transmitting), the equipment **shall** regain normal sensitivity, within 3 dB, not later than 15 microseconds after the end of the applied mutual suppression pulse.

Note: *This document does not establish the design parameters of the mutual suppression system. However, it is recommended that all sources of mutual suppression pulses be DC coupled while sinks are AC coupled. This standardization will prevent source or sink failures from disabling all users of the mutual suppression pulses.*

2.2.13 Antenna System

ADS B systems require omni-directional antenna(s) for transmitting and receiving. Separate antenna for receiving and transmitting are not required.

2.2.13.1 Transmit Pattern Gain

The gain of an omni-directional transmit antenna **shall** not be less than the gain of a matched quarter-wave stub minus 3 dB over 90 percent of a coverage volume from 0 to 360 degrees in azimuth and from 5 to 30 degrees above the ground plane when installed at center of 1.2 meter (4 feet) diameter (or larger) flat circular ground plane.

2.2.13.2 Receiver Pattern Gain

The gain of an omni-directional antenna should not be less than the gain of a matched quarter-wave stub minus one dB over 90% of a coverage volume from 0 to 360 degrees in azimuth and -15 to +20 degrees in elevation when installed at the center of a 1.2 m (4 ft.) diameter (or larger) circular ground plane that can be either flat or cylindrical.

Note: *These requirements are consistent with those provided in RTCA DO-185B, §2.2.4.7.2.1 (EUROCAE ED-143, §2.2.4.7.2.1).*

2.2.13.3 Frequency Requirements for Transmit and Receive Antenna(s)

Antenna **shall** be designed to transmit and receive signals at 1090 ±1 MHz.

2.2.13.4 Impedance and VSWR

The VSWR produced by each antenna when terminated in a 50 ohm transmission line **shall not** exceed 1.5:1 at 1090 MHz.

2.2.13.5 Polarization

Antenna(s) **shall** be vertically polarized.

2.2.13.6 Diversity Operation

Diversity transmission and/or reception is described in §3.3.1. Such implementations **shall** employ two antennas, one mounted on the top and the other on the bottom of the aircraft. Separate requirements apply to transmitting diversity and receiving diversity as provide in the following subsections.

2.2.13.6.1 Transmitting Diversity

"Transmitting diversity" refers to the alternation between the top and bottom-mounted antennas for the transmission of ADS-B Messages. If an ADS-B Transmitting Subsystem implements transmitting diversity, it **shall** transmit each required type of ADS-B Message alternately from the top and bottom antennas.

Note: *For example, successive Airborne Position Messages would be transmitted on different antennas. Again, successive messages loaded into a transponder's event-driven register would be transmitted alternately from the top and bottom antennas.*

If transmission diversity is used, the bit described in §2.2.3.2.3.3 **shall** be set valid.

2.2.13.6.1.1 Transmitting Diversity Channel Isolation

The peak RF power transmitted from the selected antenna **shall** exceed the power transmitted from the non-selected antenna by at least 20 dB.

2.2.13.6.2 Receiving Diversity

"Receiving diversity" refers to an ADS-B Receiving Subsystem's use of signals received from either the top antenna, or the bottom antenna, or both antennas. For the purpose of these requirements, several alternate ADS-B Receiving Subsystem architectures that employ receiving antenna "diversity" are illustrated in Figure 2–17.

a. Full receiver and message processing function diversity:

   (see Figure 2-23, part b1.)

   There are two receiver input channels, each with its own receiver front end, preamble detection, bit demodulation, error detection, and error correction functions. Channel selection is based on declaration of a correct message by the parity error detection function. In the event that both channels produce an identical correct message with no parity errors, the message from either channel can be selected as the received message, which is then delivered to the report assembly function. In the event each channel produces valid, but different messages, both **shall** be delivered to the report assembly function.

b. Receiver Switching Front-end Diversity:

   (see Figure 2-23, part b2.)

   There are two receiver input channels, each with its own receiver front end and preamble detection; followed by single channel bit, demodulation, error detection, and error correction functions. Channel selection is based on the detection of valid preamble pulse patterns and connection of the single string elements to the receiver input having the strongest preamble pulse pattern. In the event that the preamble pulse patterns for both channels are within 1 dB of each other, either receiver input may be selected.

c. Receiving antenna switching:

   (see Figure 2-23, part b3.)

   A single receiver input channel, consisting of receiver RF front end, preamble detection, bit demodulation, and error detection and correction functions, is internally connected alternately and periodically to the top and bottom antennas. If this method is implemented, switching **shall** cause the channel to dwell for 2.0 seconds on each antenna and continue an alternating transition every 2 ±0.1 seconds. The switching function **shall** result in loss of no more than 1 input message for each transition when the RF message signals are present at the required maximum incoming message rate of 8000 ADS-B Messages per second.

Notes:

1. *The maximum rate is derived from §2.2.4.3.4.1.which infers that the receiver sensitivity threshold will be recovered in not more than 120 microseconds after the detection of the preamble. Therefore, the minimum separation between the leading edge of the first preamble pulse of two successive ADS-B Messages is established at 125 microseconds, thereby establishing the maximum possible short term rate of 8,000 ADS-B Messages per second.*

2. *The maximum rate identified above is not typical of the future ADS-B environment and should not be applied to the ADS-B Receiving Subsystem as a steady state rate. This high rate should be applied to the ADS-B Receiving Subsystem for short durations that are adequate to demonstrate compliance of the ADS-B Receiving Subsystem.*

ADS-B Receiving Subsystems which implement antenna switching to a single receiver as discussed in §“c,” **shall** provide a method of delivering all ADS-B Messages to an appropriate output interface for the purpose of monitoring the message throughput capability of the Receiving Subsystem (see Figure 2-23, part a., “MOPS test point”).

d. Other switching diversity techniques. Other diversity implementations may be used. Any implementation must meet the requirements of (a) or (b) above.

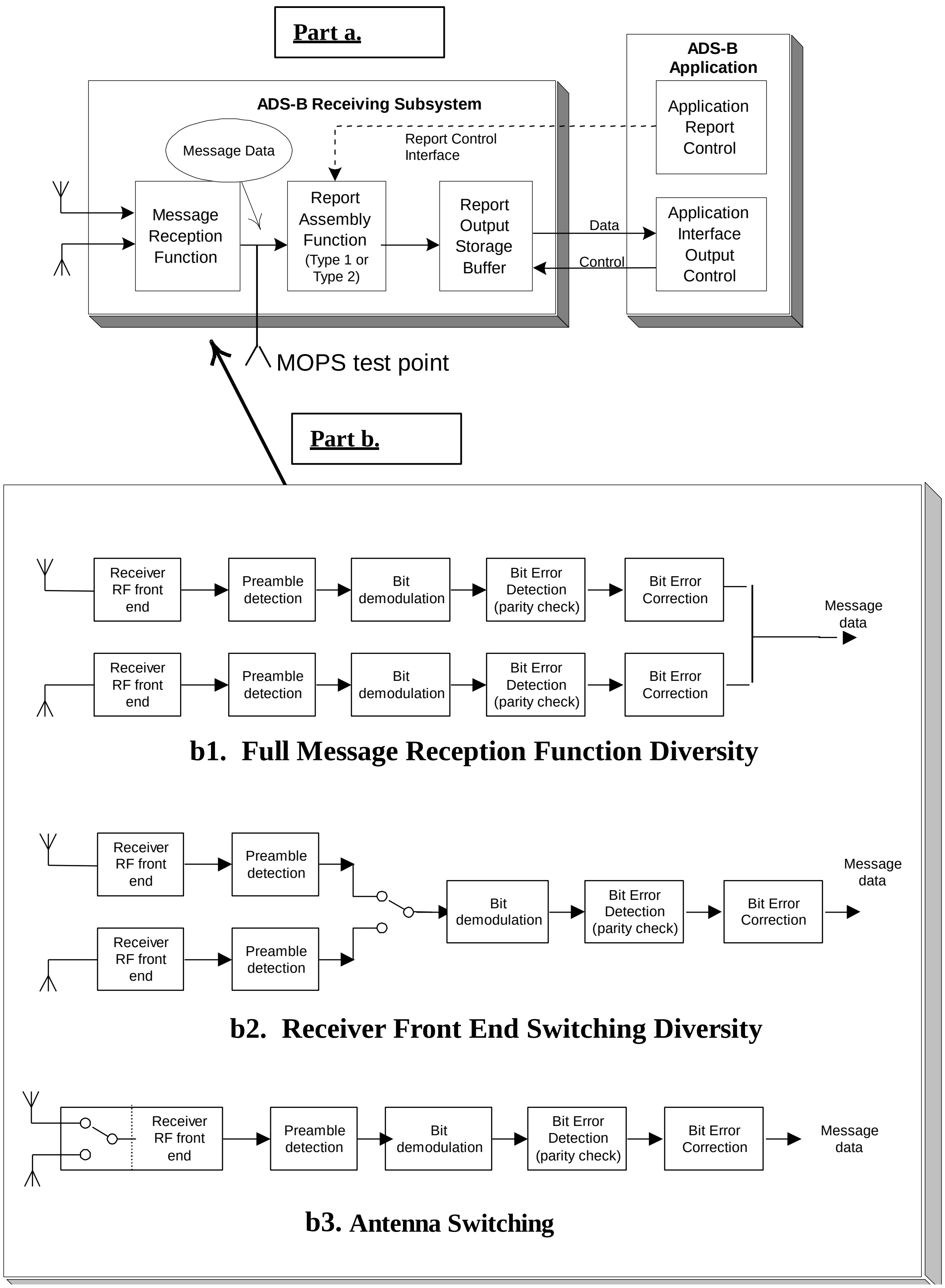


Figure 2-23: Various ADS-B Receiving Architectures.

2.2.14 Interfaces

2.2.14.1 ADS-B Transmitting Subsystem Interfaces

2.2.14.1.1 ADS-B Transmitting Subsystem Input Interfaces

Data delivery mechanisms **shall** ensure that each data parameter is provided to the input function of the ADS-B Transmitting Subsystem at sufficient update rates to support the ADS-B Message Update Rates provided in §2.2.3.3 through §2.2.3.3.2.11.

2.2.14.1.1.1 Discrete Input Interfaces

Appropriate discrete inputs may be used to provide the ADS-B Transmitting Subsystem with configuration and control information. When implemented, all discrete inputs **shall** provide appropriate diode isolation to prevent sneak current paths.

2.2.14.1.1.2 Digital Communication Input Interfaces

Approved Avionics Digital Communication interfaces **shall** be used to provide all digital data parameters (including control information) to the ADS-B Transmitting Subsystem. Such input interfaces **shall** implement appropriate error control techniques (i.e., parity as a minimum) to ensure that data is properly delivered to the ADS-B Transmitting Subsystem control and message generation functions.

2.2.14.1.1.3 Processing Efficiency

The ADS-B Transmitting Subsystem input processing function **shall** be capable of efficiently processing all data input interfaces in a manner that ensures that the most recent update received for all required data parameters is made available to the message generation function to support the rates identified in §2.2.3.3 through §2.2.3.3.2.11.

2.2.14.1.2 ADS-B Transmitting Subsystem Output Interfaces

2.2.14.1.2.1 Discrete Output Interfaces

Appropriate discrete outputs may be used by the ADS-B Transmitting Subsystem to provide Mode Status and Failure Monitoring information to other users or monitoring equipment. When implemented, all discrete outputs **shall** provide appropriate diode isolation to prevent sneak current paths.

2.2.14.1.2.2 Digital Communication Output Interfaces

Appropriate Avionics Digital Communication output interfaces **shall** be implemented by the ADS-B Transmitting Subsystem to provide status and data communication to other user or monitoring equipment. Such output interfaces **shall** implement appropriate error control techniques (i.e., parity as a minimum) to ensure that data is properly delivered to other user or monitoring equipment.

2.2.14.2 ADS-B Receiving Device Interfaces

2.2.14.2.1 ADS-B Receiving Device Input Interfaces

2.2.14.2.1.1 Discrete Input Interfaces

Appropriate discrete inputs may be used to provide the ADS-B Receiving device with configuration and control information. When implemented, all discrete inputs **shall** provide appropriate diode isolation to prevent sneak current paths.

2.2.14.2.1.2 Digital Communication Input Interfaces

Approved Avionics Digital Communication interfaces **shall** be used to provide all digital data parameters (including control information) to the ADS-B Receiving Device. Such input interfaces **shall** implement appropriate error control techniques (i.e., parity as a minimum) to ensure that data is properly delivered to the ADS-B Receiving device control and Report Assembly functions.

2.2.14.2.1.3 Processing Efficiency

The ADS-B Receiving Device input processing function **shall** be capable of efficiently processing all data input interfaces in a manner that ensures that the most recent update received for all required data parameters is made available to the Report Assembly function.

2.2.14.2.2 ADS-B Receiving Device Output Interfaces

2.2.14.2.2.1 Discrete Output Interfaces

Appropriate discrete outputs may be used by the ADS-B Receiving device to provide Mode Status and Failure Monitoring information to other users or monitoring equipment. When implemented, all discrete outputs **shall** provide appropriate diode isolation to prevent sneak current paths.

2.2.14.2.2.2 Digital Communication Output Interfaces

Appropriate Avionics Digital Communication output interfaces **shall** be implemented by the ADS-B Receiving device to provide status and data communication to other user or monitoring equipment. Such output interfaces **shall** implement appropriate error control techniques (i.e., parity as a minimum) to ensure that data is properly delivered to other user or monitoring equipment.

2.2.15 Power Interruption

The ADS-B transmitting and/or receiving equipment **shall** regain operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

Note: *The ADS-B transmitting and/or receiving equipment is not required to continue operation during momentary power interruptions.*

2.2.16 Compatibility with Other Systems

2.2.16.1 EMI Compatibility

The ADS-B transmitting and/or receiving equipment **shall** not compromise the operation of any co-located communication or navigation equipment, or ATCRBS and/or Mode-S transponders. Likewise, the ADS-B antenna **shall** be mounted such that it does not compromise the operation of any other proximate antenna.

2.2.16.2 Compatibility with GPS Receivers

The ADS-B transmitting and/or receiving equipment **shall** not compromise the operation of a co-located proximate GPS receiver.

2.2.16.3 Compatibility with Other Navigation Receivers and ATC Transponders

The ADS-B transmitting and/or receiving equipment **shall** not compromise the operation of VOR, DME, ADF, LORAN, ATCRBS or Mode-S equipment installed in a proximate location.

In addition, the ADS-B receiver must be fully operational when located in close proximity of an ATCRBS or Mode-S transponder.

2.2.17 Traffic Information Services – Broadcast (TIS-B)

2.2.17.1 Introduction

This section defines the formats and coding for a Traffic Information Service Broadcast (TIS-B) based on the same 112-bit 1090 MHz signal transmission that is used for ADS-B on 1090 MHz.

TIS-B complements the operation of ADS-B by providing ground-to-air broadcast of surveillance data on aircraft that are not equipped for 1090 MHz ADS-B. The basis for this ground surveillance data may be an ATC Mode S radar, a surface or approach multi-lateration system or a multi-sensor data processing system. The TIS-B ground-to-air transmissions use the same signal formats as 1090 MHz ADS-B and can therefore be accepted by a 1090 MHz ADS-B receiver.

TIS-B service is the means for providing a complete surveillance picture to 1090 MHz ADS-B users during a transition period. After transition, it also provides a means to cope with a user that has lost its 1090 MHz ADS-B capability.

2.2.17.2 TIS-B Format Structure

TIS-B information is broadcast using the 112-bit Mode S DF=18 format as shown in Figure 2-24.

TIS-B Baseline Format Definition					
Bit #	1 ----- 5	6 --- 8	9 -------- 32	33 ---------------------------- 88	89 ------ 112
DF=18	**DF [5]**	**CF [3]**	**AA [24]**	**ME [56]**	**PI [24]**
	10010				
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB

Figure 2-24: TIS-B Baseline Format Definition

The content of the DF=18 transmission is defined by the value of the Control Field (CF), as specified in Table 2-106.

Table 2-106: "CF" Field Code Definitions in DF=18 ADS-B and TIS-B Messages

CF Value	ICAO/Mode A Flag (IMF)	Meaning
0	N/A	ADS-B Message from a non-transponder device, AA field holds 24-bit ICAO aircraft address
1	N/A	Reserved for ADS-B Message in which the AA field holds anonymous address or ground vehicle address or fixed obstruction address
2	0	Fine TIS-B Message, AA field contains the 24-bit ICAO aircraft address
	1	Fine TIS-B Message, AA field contains the 12-bit Mode A code followed by a 12-bit track file number
3	0	Coarse TIS-B Airborne Position and Velocity Message, AA field contains the 24-bit ICAO aircraft address
	1	Coarse TIS-B Airborne Position and Velocity Message, AA field contains the 12-bit Mode A code followed by a 12-bit track file number.
4	N/A	TIS-B and ADS-R Management Message AA contains TIS-B/ADS-R management information.
5	0	Fine TIS-B Message AA field contains a non-ICAO 24-bit address
	1	Reserved
6	0	Rebroadcast of ADS-B Message from an alternate data link. AA field holds 24-bit ICAO aircraft address
	1	Rebroadcast of ADS-B Message from an alternate data link. AA field holds anonymous address or ground vehicle address or fixed obstruction address
7	N/A	Reserved

2.2.17.2.1 "DF" Downlink Format

This field will be set to DF=18 for TIS-B to indicate that this transmission is not from a Mode S transponder. See §2.2.3.2.1.1.

2.2.17.2.2 "CF" Control Field

The "CF" field of DF=18 messages is a 3-bit field (bits 6 through 8) used by Non-Transponder-Based installations. This field will be set to 2, 3, 4 or 5 depending upon the TIS-B Message as specified in Table 2-106. The ADS-B Receiving Subsystem **shall** accept and process DF=18, with CF=2, CF=3, CF=4 and CF=5 as TIS-B Messages.

2.2.17.2.3 "AA" Address Announced Field

As specified in Table 2-106, the ADS-B Receiving Subsystem **shall** interpret the AA field as either:

(1) the 24-bit aircraft address as specified in §2.2.3.2.1.1, or

(2) the 12-bit Mode A code followed by a 12-bit track number.

2.2.17.2.4 "ME" Message Extended Squitter Field

This field is specified in §2.2.3.2.1.6.

2.2.17.2.5 "PI" Parity/Identity Field

This field is specified in §2.2.3.2.1.7.

2.2.17.3 TIS-B Messages

2.2.17.3.1 TIS-B Fine Airborne Position Message

TIS-B Fine Airborne Position Message Format								
MSG BIT #	33 --- 37	38 --------- 39	40	41 ----- 52	53	54	55 -------- 71	72 -------- 88
“ME” BIT #	1 ----- 5	6 ------------ 7	8	9 ----- 20	21	22	23 -------- 39	40 -------- 56
Field Name	**TYPE [5]**	**Surveillance Status [2]**	**IMF [1]**	**Pressure Altitude [12]**	**Reserved [1]**	**CPR Format (F) [1]**	**CPR Encoded Latitude [17]**	**CPR Encoded Longitude [17]**
	MSB LSB	MSB LSB		MSB LSB			MSB LSB	MSB LSB

Note: *“[#]” provided in the Field Name column indicates the number of bits in the respective field.*

Figure 2-25: TIS-B Fine Airborne Position Message Format

2.2.17.3.1.1 Relationship to ADS-B Format

The following fields **shall** be decoded as specified for the ADS-B Airborne Position Message defined in §2.2.3.2.3:

TYPE Code	Surveillance Status
Altitude	CPR Format
Encoded Latitude	Encoded Longitude

The TYPE Code **shall** be decoded according to the TYPE Code Format in Table N-XXXXXX.

Note: *TIS-B Service Airborne Position Message TYPE Codes are consistent with ADS-B Version ONE (1) definitions.*

2.2.17.3.1.2 ICAO/Mode A Flag (IMF)

This 1-bit (“ME” bit 8) field **shall** be used to indicate the type of identity associated with the aircraft data reported in the TIS-B Message. IMF equal to ZERO (0) **shall** indicate that the TIS-B data is identified by an 24-bit Aircraft address. IMF equal to ONE (1) indicates that the TIS-B data is identified by a “Mode A” Code. A “Mode A” Code of all ZEROs indicates a primary radar target.

Note: *The AA field is coded differently for 24-bit addresses and Mode A codes as specified in Table 2-106.*

2.2.17.3.2 TIS-B Fine Surface Position Message

TIS-B Fine Surface Position Message Format								
MSG BIT #	33 -- 37	38 ------- 44	45	46 ----- 52	53	54	55 ------- 71	72 -------- 88
"ME" BIT #	1 ----- 5	6 --------- 12	13	14 ----- 20	21	22	23 ------- 39	40 -------- 56
Field Name	**TYPE [5]**	**Movement [7]**	**Heading Status [1]**	**Heading [7]**	**IMF [1]**	**CPR Format (F) [1]**	**CPR Encoded Latitude [17]**	**CPR Encoded Longitude [17]**
	MSB LSB	MSB LSB		MSB LSB			MSB LSB	MSB LSB

Note: *"[#]" provided in the Field Name column indicates the number of bits in the respective field.*

Figure 2-26: TIS-B Fine Surface Position Message Format

2.2.17.3.2.1 Relationship to ADS-B Format

The following fields **shall** be coded as specified for the ADS-B Surface Position Message defined in §2.2.3.2.4:

TYPE Code	Movement
Heading Status	Heading
CPR Format	Encoded Latitude
Encoded Longitude	

The TYPE Code **shall** be decoded according to the TYPE Code Format in Table N-XXXXXX.

Note: *TIS-B Service Surface Position Message TYPE Codes are consistent with ADS-B Version ONE (1) definitions.*

2.2.17.3.2.2 ICAO/Mode A Flag (IMF)

This 1-bit ("ME" bit 21) field **shall** be set as specified in §2.2.17.3.1.2.

2.2.17.3.3 TIS-B Identification and Category Message

TIS-B Identification and Category Message Format										
MSG BIT #	33 - 37	38 - 40	41 - 46	47 - 52	53 - 58	59 - 64	65 - 70	71 - 76	77 - 82	83 – 88
"ME" BIT #	1 - 5	6 - 8	9 - 14	15 - 20	21 - 26	27 - 32	33 - 38	39 - 44	45 - 50	51 – 56
FIELD NAME	**TYPE [5]**	**Emitter Category [3]**	**Ident Char #1 [6]**	**Ident Char #2 [6]**	**Ident Char #3 [6]**	**Ident Char #4 [6]**	**Ident Char #5 [6]**	**Ident Char #6 [6]**	**Ident Char #7 [6]**	**Ident Char #8 [6]**
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB

Note: *"[#]" provided in the Field Name column indicates the number of bits in the respective field.*

Figure 2-27: TIS-B Identification and Category Message Format

2.2.17.3.3.1 Relationship to ADS-B Format

All of the fields of the TIS-B Identification and Category Message **shall** be coded as specified for the ADS-B Identification and Category Message specified in §2.2.3.2.5.

Note: *This message will only be used for aircraft identified with a 24-bit Aircraft address.*

2.2.17.3.4 TIS-B Velocity Message

TIS-B Velocity Message – Subtypes "1" and "2"															
MSG BIT #	33 - 37	38 - 40	41	42 - 45	46	47 - 56	57	58 - 67	68	69	70 - 78	79	80 - 82	83 - 84	85 – 88
"ME" BIT #	1 - 5	6 - 8	9	10 - 13	14	15 - 24	25	26 - 35	36	37	38 - 46	47	48 - 50	51 - 52	53 – 56
FIELD NAME	**TYPE [5]**	**Subtype [3]**	**IMF [1]**	**NAC_P [4]**	**E/W Direction Bit [1]**	**E/W Velocity [10]**	**N/S Direction Bit [1]**	**N/S Velocity [10]**	**GEO Flag =0 [1]**	**Vertical Rate Sign Bit [1]**	**Vert Rate [9]**	**NIC Supplement [1]**	**NAC_V [3]**	**SIL [2]**	**Reserved [4]**
									GEO Flag =1 [1]				**Reserved [1]** / **Difference Sign Bit [1]**	**Geometric Height Difference From Barometric [7]**	
	MSB LSB	MSB LSB		MSB LSB		MSB LSB		MSB LSB			MSB LSB		MSB LSB	MSB LSB	MSB LSB

Note: *"[#]" provided in the Field Name column indicates the number of bits in the respective field.*

Figure 2-28: TIS-B Velocity Message, Subtypes 1 and 2

<table>
<tr><th colspan="22">TIS-B Velocity Message – Subtypes “3” and “4”</th></tr>
<tr><td>MSG BIT #</td><td>33 - 37</td><td>38 - 40</td><td>41</td><td>42 - 45</td><td>46</td><td>47 - 56</td><td>57</td><td>58 - 67</td><td>68</td><td>69</td><td>70 - 78</td><td>79</td><td colspan="3">80 - 82</td><td colspan="2">83 - 84</td><td colspan="4">85 – 88</td></tr>
<tr><td>“ME” BIT #</td><td>1 - 5</td><td>6 - 8</td><td>9</td><td>10 - 13</td><td>14</td><td>15 - 24</td><td>25</td><td>26 - 35</td><td>36</td><td>37</td><td>38 - 46</td><td>47</td><td colspan="3">48 - 50</td><td colspan="2">51 - 52</td><td colspan="4">53 – 56</td></tr>
<tr><td rowspan="2">FIELD NAME</td><td rowspan="2">TYPE [5]</td><td rowspan="2">Subtype [3]</td><td rowspan="2">IMF [1]</td><td rowspan="2">NAC_P [4]</td><td rowspan="2">Heading Status Bit [1]</td><td rowspan="2">Heading [10]</td><td rowspan="2">Airspeed Typet [1]</td><td rowspan="2">Airspeed [10]</td><td>GEO Flag =0 [1]</td><td rowspan="2">Vertical Rate Sign Bit [1]</td><td rowspan="2">Vert Rate [9]</td><td rowspan="2">NIC Supplement [1]</td><td colspan="3">NAC_V [3]</td><td colspan="2">SIL [2]</td><td colspan="2">Reserved [2]</td><td>True/Mag [1]</td><td>Reserved [1]</td></tr>
<tr><td>GEO Flag =1 [1]</td><td>Reserved [1]</td><td>Difference Sign Bit [1]</td><td colspan="7">Geometric Height Difference From Barometric [7]</td></tr>
<tr><td></td><td>MSB LSB</td><td>MSB LSB</td><td></td><td>MSB LSB</td><td></td><td>MSB LSB</td><td></td><td>MSB LSB</td><td></td><td></td><td>MSB LSB</td><td></td><td colspan="3">MSB LSB</td><td colspan="2">MSB LSB</td><td colspan="4">MSB LSB</td></tr>
</table>

Note: *“[#]” provided in the Field Name column indicates the number of bits in the respective field.*

Figure 2-29: TIS-B Velocity Message, Subtypes 3 & 4

2.2.17.3.4.1 Relationship to ADS-B Format

The following fields **shall** be coded as specified for the ADS-B Velocity Message with Subtype=1, as specified in §2.2.3.2.6.1, or Subtype=2, as specified in §2.2.3.2.6.2:

TYPE Code	Subtype Code
E/W Direction Bit	E/W Velocity
N/S Direction Bit	N/S Velocity
Vertical Rate Sign	Vertical Rate
Height Difference Sign Bit	Geometric Height Difference from Baro
Vertical Rate Type	

2.2.17.3.4.2 ICAO/Mode A Flag (IMF)

This one-bit (“ME” bit 9) field **shall** be set as specified in §2.2.17.3.1.2.

2.2.17.3.4.3 Navigation Integrity Code (NIC) Supplement

This one-bit (“ME” bit 47) field **shall** be used together with the Message TYPE Code to define the NIC value for the Airborne and Surface Position Messages.

Coding of the NIC Supplement field **shall** be as specified in Table N-XXXXX.

2.2.17.3.4.4 Navigation Accuracy Category for Position (NAC_P)

This four-bit (“ME” bits 10 through 13) field **shall** define the NAC_P value for the Airborne and Surface Position Messages.

Coding of the NAC_P field **shall** be as specified for the Aircraft Operational Status Message in Table 2-71.

2.2.17.3.4.5 Navigation Accuracy Category for Velocity (NAC_V)

This 3-bit (“ME” bits 48 through 50) field **shall** define the NAC_V value for the Airborne Velocity Message when the GEO Flag is equal to ZERO (0). Coding of the NAC_V field **shall** be as specified in §2.2.3.2.6.1.5.

2.2.17.3.4.6 Surveillance Integrity Level (SIL)

This two-bit (“ME” bits 52 and 53) field **shall** define the SIL value for the Airborne and Surface Position Messages when the GEO Flag is equal to ZERO (0). Coding of the SIL field **shall** be as specified in Table N-XXXXX.

2.2.17.3.4.7 True/Magnetic Heading Type

This one-bit (“ME” bit 55) field **shall** define the True or Magnetic Heading value for the Airborne Velocity Message when the GEO Flag is equal to ZERO (0) for a Subtype of 3 or 4. Coding of the True/Magnetic Heading Type field **shall** be as specified in §2.2.3.2.7.2.13.

2.2.17.3.5 TIS-B Coarse Position Message

TIS-B Coarse Position Message Format										
MSG BIT #	33	34 ------- 35	36 -----39	40 -- 51	52	53 --- 57	58 -- 63	64	65 ------ 76	77 ------ 88
"ME" BIT #	1	2 --------- 3	4 ------- 7	8 ---19	20	21 --- 25	26 -- 31	32	33 ------ 44	45 ------ 56
Field Name	IMF [1]	Surveillance Status [2]	Service Volume ID (SVID) [4]	Pressure Altitude [12]	Ground Track Status [1]	Ground Track Angle [5]	Ground Speed [6]	CPR Format (F) [1]	CPR Encoded Latitude [12]	CPR Encoded Longitude [12]
		MSB LSB	MSB LSB	MSB LSB		MSB LSB	MSB LSB		MSB LSB	MSB LSB

Note: *"[#]" provided in the Field Name column indicates the number of bits in the respective field.*

Figure 2-30: TIS-B Coarse Position Message Format

2.2.17.3.5.1 Relationship to ADS-B Format

The format of the TIS-B Coarse Position Message is not related to any ADS-B format. The format is specified in the following subparagraphs.

2.2.17.3.5.2 ICAO/Mode A Flag (IMF)

This one-bit ("ME" bit 1) field **shall** be set as specified in §2.2.17.3.1.2.

2.2.17.3.5.3 Service Volume ID (SVID)

The 4-bit ("ME" bits 4 through 7) SVID field **shall** be decoded to identify the TIS-B site that delivered the surveillance data.

Note: *In the case where TIS-B Messages associated with a specific target are being received from more than one TIS-B ground station, the receiving application can use the SVID to select coarse messages from a single source. This will prevent the receiving application's TIS-B track from wandering due to the different error biases associated with different sources.*

2.2.17.3.5.4 Pressure Altitude

This 12-bit ("ME" bits 8 – 19) field **shall** be decoded as specified in §2.2.3.2.3.4.1.

2.2.17.3.5.5 Ground Track Status

This one bit ("ME" bit 20) field **shall** define the validity of the Ground Track value. Coding for this field **shall** be as follows: 0=not valid and 1= valid.

2.2.17.3.5.6 Ground Track Angle

This 5-bit ("ME" bits 21 through 25) field **shall** define the direction (in degrees clockwise from true north) of aircraft motion. The Ground Track **shall** be encoded as an unsigned angular weighted binary numeral, with an MSB of 180 degrees and an LSB of 360/32 degrees, with ZERO (0) indicating true north. The data in the field **shall** be rounded to the nearest multiple of 360/32 degrees.

2.2.17.3.5.7 Ground Speed

This 6-bit ("ME" bits 26 through 31) field **shall** define the aircraft speed over the ground. Coding of this field **shall** be as shown in Table 2-107.

Table 2-107: Ground Speed Encoding

Coding		Meaning
(Binary)	(Decimal)	(Ground Speed in knots)
00 0000	0	No Ground Speed information available
00 0001	1	Ground Speed < 16 knots
00 0010	2	16 knots ≤ GS < 48 knots
00 0011	3	48 knots ≤ GS < 80 knots
***	***	***
11 1110	62	1936 knots ≤ GS < 1968 knots
11 1111	63	GS ≥ 1968 knots

Notes:

1. *The encoding shown in the table represents Positive Magnitude data only.*
2. *Raw data used to establish the Ground Speed Subfield will normally have more resolution (i.e., more bits) than that required by the Ground Speed Subfield. When converting such data to the Ground Speed Subfield, the accuracy of the data must be maintained such that it is not worse than ±½ LSB where the LSB is that of the Ground Speed Subfield.*

2.2.17.3.5.8 Encoded Latitude and Longitude

The Encoded Latitude field **shall** be decoded consistent with the format specified in §2.2.3.2.3.7, except that the 12-bit CPR coding specified in Appendix A, §A.1.7 **shall** be used.

The Encoded Longitude field **shall** be decoded consistent with the format specified in §2.2.3.2.3.8, except that the 12-bit CPR coding specified in Appendix A, §A.1.7 **shall** be used.

2.2.17.4 TIS-B Message Processing and Report Generation

The information received in TIS-B Messages is reported directly to applications, with one exception. The exception is latitude-longitude position information, which is CPR-encoded when it is received, and must be decoded before reporting. In order to accomplish CPR decoding, it is necessary to track received messages, so that even-format and odd-format messages can be combined to determine the latitude and longitude of the target.

In the most common case, a particular target will result in TIS-B Message receptions or ADS-B Message receptions, but not both. It is possible, however, for both types of messages to be received for a single target. If this happens, the TIS-B information is processed and reported independently of the ADS-B receptions and reporting.

2.2.17.4.1 TIS-B Message-to-Track Correlation

Tracking makes it possible to associate a received message with information previously received about that same target, in the presence of many other intervening messages about other targets. Such associations are necessary for global decodes (§2.2.17.4.2), for estimating velocity when position was received (§2.2.17.4.6) and for estimating position when velocity was received (§2.2.17.4.6).

2.2.17.4.1.1 TIS-B Messages Having a 24-Bit ICAO Address

For a target that has a 24-bit ICAO Address, that address is used for correlating new receptions with information in the TIS-B track file. Correlation is successful if the address matches exactly. When a TIS-B Position Message having a 24-bit ICAO Address is received, and an existing TIS-B track has the same address, the message **shall** be correlated with the track.

2.2.17.4.1.2 TIS-B Messages Having Mode A Code and Track Number

For a target not identified by a 24-bit ICAO Address, but instead having a Mode A Code and a TIS-B track number, then these are used to correlate with information in the track file. Correlation is successful if the Mode A Code and the track number both match exactly. When a TIS-B Message having a Mode A Code and TIS-B track number is received, and an existing TIS-B track has the same Mode A Code and ADS-B track number, the message **shall** be correlated with the track.

2.2.17.4.2 TIS-B Position Message Decoding

When a received TIS-B Position Message correlates to an existing TIS-B track, the message and the track are used together to decode the latitude and longitude of the target. If the track is "Complete," meaning that a global decode has been accomplished, then the new latitude-longitude information **shall** be decoded using local decoding, as specified in §A.1.7.4 in Appendix A, taking the previous position of the target as the reference.

If the TIS-B track is "Incomplete," meaning that a global decode has not yet been accomplished prior to this reception, then a global decode may be computed depending on the contents of the track. If the information in the track together with the new position message consist of at least one even format message and at least one odd format message received within 10 seconds, then a global decode **shall** be computed as specified in

§A.1.7.7 of Appendix A. Otherwise the received encoded position, the even/odd format, and the time of applicability, **shall** be saved in the track file for later use.

Note: *When decoding positions, a reasonableness test may be applied.*

2.2.17.4.3 TIS-B Track Update

When a position message is correlated to a TIS-B track that is Complete, then a new position is computed as specified in §2.2.17.4.2 and the tracked position **shall** be updated with the new position and time of applicability. The previous position and time need not be saved. Figure 2-31 illustrates the transition from Incomplete track to Complete track and later track drop.

When a position message is correlated with a TIS-B track that is Incomplete, the new information may make it possible for a global decode, as specified in §2.2.17.4.2. If a global decode is accomplished, the track **shall** be promoted to Complete, and the latitude, longitude, and time of applicability **shall** be saved in the track. The previous position and time information need not be saved. If a global decode is not accomplished, the even and odd encoded positions **shall** be saved for future decodes.

Note: *It is not necessary to save any encoded positions longer than 10 seconds.*

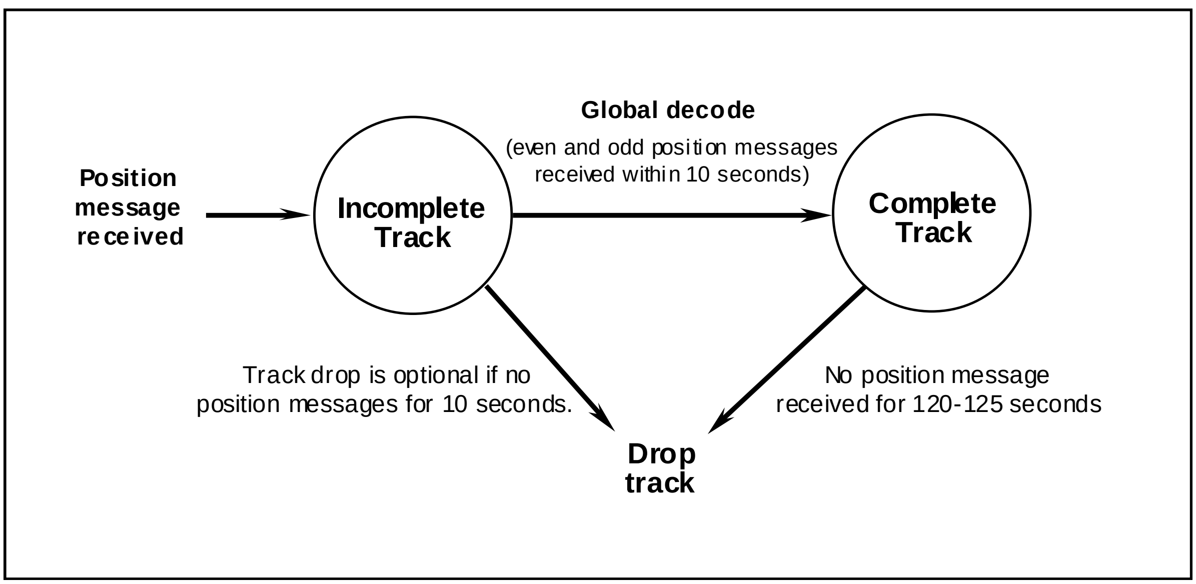


Figure 2-31: **TIS-B Tracks**

2.2.17.4.4 TIS-B Track Initiation

A TIS-B track begins with the reception of one position message. A new Incomplete track **shall** be created, and the encoded position, even/odd format bit, and time of applicability **shall** be saved.

2.2.17.4.5 TIS-B Track Drop

A TIS-B track that is Complete **shall** not be dropped within 120 seconds after any TIS-B Position Message reception. If 125 seconds elapses without any TIS-B Message reception, the track **shall** be dropped.

Note: *As specified in §2.2.17.4.3, for an Incomplete TIS-B track, it is not necessary to save any information more than 10 seconds after reception. Therefore the track can be dropped after 10 seconds.*

2.2.17.4.6 TIS-B Report Generation

As TIS-B Messages are received, the information is reported to applications. All received information elements, other than position, **shall** be reported directly, including all reserved fields for the TIS-B fine format messages (§2.2.17.3.1 to §2.2.17.3.4) and the entire message content (i.e., including the complete 88-bit content of the DF, CF, AA and ME fields of the Extended Squitter Message) of any received TIS-B Management Message (Table 2-106, for CF=4). The reporting format is not specified in detail, except that the information content reported **shall** be the same as the information content received. The report **shall** be issued within 0.5 seconds of the message reception.

When a TIS-B Position Message is received, it is compared with tracks to determine whether it can be decoded into target position, as specified in §2.2.17.4.2. If the message is decoded into target position, a report **shall** be generated, within 0.5 seconds of the message reception. The report **shall** contain the received position information with its time of applicability, the most recently received velocity measurement with its time of applicability, estimated position and velocity, applicable to a common time of applicability, address, and all other information in the received message. The estimated values **shall** be based on the received position information and the track history of this target.

When a TIS-B Velocity Message is received, if it is correlated to a complete track, then a report **shall** be generated, within 0.5 seconds of the message reception. The report **shall** contain the received velocity information with its time of applicability, the most recently received position measurement with its time of applicability, estimated position and velocity, applicable to a common time of applicability, address, and all other information in the received message. The estimated values **shall** be based on the received ground referenced velocity information and the track history of this target.

Notes:

1. *Whereas ADS-B reports are classified as to "State Vector Reports" and certain other defined types, TIS-B reports are not. Instead, TIS-B reporting follows the general principle that all received information is reported directly upon reception.*

2. *In the absence of TIS-B Message receptions, it is possible for reports to be generated, but this is not required. Such additional reports might be useful as a means of counteracting possible flaws in an on-board data bus between ADS-B and an application.*

3. *Track drop (§2.2.17.4.5) is the only TIS-B function for which time-out performance is required. It is expected that TIS-B applications will take account of the times when information is reported and will apply the time-out functions that are appropriate for each application.*

2.2.18 ADS-B Rebroadcast Service – Formats and Coding

2.2.18.1 Introduction

The TIS-B MASPS, RTCA DO-286B defines, in addition to the "Fundamental TIS-B Service," an "ADS-B Rebroadcast Service" as an additional service that may be provided. The Messages of the ADS-B Rebroadcast Service are not transmitted by aircraft, but by ADS-B ground stations.

Notes:

1. *This section defines the formats and coding for an ADS-B Rebroadcast (ADS-R) Service (see the TIS-B MASPS, RTCA DO-286B, §1.4.1) based on the same 112-bit 1090 MHz Extended Squitter signal transmission that is used for DF=17 ADS-B Messages on 1090 MHz.*

2. *The ADS-B Rebroadcast Service complements the operation of ADS-B and the Fundamental TIS-B Service (see the TIS-B MASPS, RTCA DO-286B, §1.4.1) by providing ground-to-air rebroadcast of ADS-B data about aircraft that are not equipped for 1090 MHz Extended Squitter ADS-B, but are equipped with an alternate form of ADS-B (e.g., Universal Access Transceiver (UAT)). The basis for the ADS-R transmission is the ADS-B Report received at the Ground Station using a receiver compatible with the alternate ADS-B data link.*

3. *The ADS-R ground-to-air transmissions use the same signal formats as the DF=17 1090 MHz Extended Squitter ADS-B and can therefore be accepted by a 1090 MHz ADS-B Receiving Subsystem, with the exceptions identified in the following sections.*

2.2.18.2 ADS-B Rebroadcast Format Definition

ADS-B Rebroadcast information is transmitted using the 112-bit Mode S DF=18 format specified in Figure 2-2.

2.2.18.3 Control Field Allocation

The content of the DF=18 transmission is defined by the value of the Control Field (CF). As specified in Table 2-11, ADS-B Rebroadcast (i.e., ADS-R) transmissions use CF=6, and ADS-R Management information transmissions (i.e., defining ADS-R Service Volume and service availability) use CF=4. The ADS-B Receiving Subsystem **shall** accept and process ADS-R Messages, DF=18, with CF=4 and CF=6.

2.2.18.4 ADS-R Message Processing

The Rebroadcast of ADS-B information on the 1090 MHz Extended Squitter data link is accomplished by utilizing the same ADS-B Message formats used by aircraft/vehicles with the exception of the need to transmit an indication to the 1090 MHz Receiving Subsystem as to the type of identity associated with the aircraft data being reported in the ADS-B Rebroadcast Message. This identification is performed using the ICAO/Mode A Flag (IMF), which was previously discussed in §2.2.17.3.1.2 for the TIS-B transmissions.

The insertion of this one bit into the ADS-B Messages identified in the subparagraphs below allows the ADS-B Receiving Subsystem to interpret the Address Field (AF) in the following manner:

IMF = 0 indicates that the ADS-B Rebroadcast data is identified by an ICAO 24-bit Address.

IMF = 1 indicates that the ADS-B Rebroadcast data is identified by an anonymous 24-bit address or ground vehicle address or fixed obstruction address.

The ADS-B Receiving Subsystem outputs data to ADS-B applications for aircraft/vehicles received via ADS-R Messages similar to direct reception of ADS-B Messages from aircraft/vehicles. ADS-R Messages may be received from a Ground Station transmitting ADS-B Version ONE (1) or Version TWO (2) Messages that have been received by the Ground Station from an aircraft or vehicle transmitting on an alternate ADS-B data link. Therefore, to correctly decode the data, knowledge of the MOPS ADS-B Version Number is required. The ADS-B Receiving Subsystem **shall** decode all valid ADS-R transmitted messages and structure the information from such received messages into the appropriate ADS-B Reports as per §2.2.8 and designate them as ADS-R Reports.

Note: *ADS-B applications may need to distinguish ADS-B Reports generated from direct receipt and those received via ADS-R.*

2.2.18.4.1 Rebroadcast of ADS-B Airborne Position Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Airborne Position Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2.2.18.4.1.

Note:

1. *The format is identical to the Airborne Position Message depicted in Figure 2-3, except that ME bit 8 is redefined to be the ICAO/Mode A Flag (IMF).*

2. *The interpretation of the TYPE Code is different between ADS-B Version ONE (1) and Version TWO (2). See Appendix N-XXXXX for decoding Version ONE (1) and §2.2.3.2.3 for decoding Version TWO (2).*

ADS-R Airborne Position Message "ME" Field								
Msg Bit #	33 -37	38 ---------- 39	40	41 ----- 52	53	54	55 ---- 71	72 ---- 88
"ME" Bit #	1 – 5	6 ------------ 7	8	9 ----- 20	21	22	23 --- 39	40 --- 56
Field Name	**TYPE Code [5]**	**Surveillance Status [2]**	**IMF [1]**	**Altitude [12]**	**Time (T) [1]**	**CPR Format (F) [1]**	**CPR Encoded Latitude [17]**	**CPR Encoded Longitude [17]**
	MSB LSB	MSB LSB		MSB LSB			MSB LSB	MSB LSB

Figure 2.2.18.4.1: ADS-R Airborne Position Message Format

2.2.18.4.2 ADS-R Surface Position Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Surface Position Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2.2.18.4.2.

Note: *The format is identical to the ADS-B Surface Position Message depicted in Figure 2-5, except that ME bit 21 is redefined to be the ICAO/Mode A Flag (IMF).*

ADS-R Surface Position Message "ME" Field								
Msg Bit #	33 - 37	38 - 44	45	46 - 52	53	54	55 - 71	72 - 88
"ME" Bit #	1 - 5	6 - 12	13	14 - 20	21	22	23 - 39	40 – 56
Field Name	**TYPE Code [5]**	**Movement [7]**	**Heading/ Ground Track Status [1]**	**Heading/ Ground Track [7]**	**IMF [1]**	**CPR Format (F) [1]**	**CPR Encoded Latitude [17]**	**CPR Encoded Longitude [17]**
	MSB LSB	MSB LSB		MSB LSB			MSB LSB	MSB LSB

Figure 2.2.18.4.2: ADS-R Surface Position Message Format

2.2.18.4.3 ADS-R Aircraft Identification and Category Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Aircraft Identification and Category Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2-6.

Note: *Any Rebroadcast ADS-B Aircraft Identification and Category Message does not contain the IMF bit since aircraft using an anonymous 24-bit address will not provide identity and category information.*

2.2.18.4.4 ADS-R Airborne Velocity Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Airborne Velocity Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2.2.18.4.4-1 for Subtype 1 & 2 Messages, and in Figure 2.2.18.4.4-2 for Subtype 3 & 4 Messages.

Notes:

1. *The formats are identical to the ADS-B Airborne Velocity Messages depicted in Figure 2-7 for Subtype 1 & 2 Messages, and in Figure 2-8 for Subtype 3 & 4 Messages, except that ME bit 9 is redefined to be the ICAO/Mode A Flag (IMF).*

2. *Bit 10 of the ME field in ADS-B Version ONE (1) is the IFR Capability Flag which is not conveyed in ADS-B Version TWO (2) ADS-B Transmitting Subsystems.*

ADS-R Airborne Velocity Message Subtype=1 and "2" "ME" Field															
MSG BIT #	33 - 37	38 - 40	41	42	43 - 45	46	47 - 56	57	58 - 67	68	69	70 - 78	79 - 80	81	82 – 88
"ME" BIT #	1 - 5	6 - 8	9	10	11 - 13	14	15 - 24	25	26 - 35	36	37	38 - 46	47 - 48	49	50 – 56
FIELD NAME	TYPE [5]	Subtype [3]	IMF [1]	Reserved-A [1]	NAC_V [3]	E/W Direction Bit [1]	E/W Velocity [10]	N/S Direction Bit [1]	N/S Velocity [10]	Vert Rate Source [1]	Vert Rate Sign [1]	Vert Rate [9]	Reserved-B [2]	Diff from Baro Alt Sign [1]	Diff from Baro Alt [7]
	MSB LSB	MSB LSB			MSB LSB		MSB LSB		MSB LSB			MSB LSB	MSB LSB		MSB LSB

Figure 2.2.18.4.4-1: ADS-R Airborne Velocity Message Subtype "1 & 2" Format

ADS-R Airborne Velocity Message Subtype=3 and "4" "ME" Field															
MSG BIT #	33 - 37	38 - 40	41	42	43 - 45	46	47 - 56	57	58 - 67	68	69	70 - 78	79 - 80	81	82 – 88
"ME" BIT #	1 - 5	6 - 8	9	10	11 - 13	14	15 - 24	25	26 - 35	36	37	38 - 46	47 - 48	49	50 – 56
FIELD NAME	TYPE [5]	Subtype [3]	IMF [1]	Reserved-A [1]	NAC_V [3]	Heading Status Bit [1]	Heading [10]	Airspeed Type [1]	Airspeed [10]	Vert Rate Source [1]	Vert Rate Sign [1]	Vert Rate [9]	Reserved-B [2]	Diff from Baro Alt Sign [1]	Diff from Baro Alt [7]
	MSB LSB	MSB LSB			MSB LSB		MSB LSB		MSB LSB			MSB LSB	MSB LSB		MSB LSB

Figure 2.2.18.4.4-2: ADS-R Airborne Velocity Message Subtype "3 & 4" Format

2.2.18.4.5 ADS-R Aircraft Emergency/Priority Status Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Aircraft Emergency/Priority Status Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2.2.18.4.5.

Notes:

1. *The format is identical to the Aircraft Emergency/Priority Status Message depicted in Figure 2-13, except that ME bit 56 is redefined to be the ICAO/Mode A Flag (IMF).*

2. *The Mode A Code, bits 12 through 24 of the ME field are not conveyed in ADS-B Version ONE (1) Aircraft Emergency/Priority Status Messages (See Appendix N, §XXXXX).*

"ADS-R Aircraft Status Message (Emergency/Priority Status) (TYPE=28, Subtype=1)"						
Msg Bit #	33 ----- 37	38 ------ 40	41 -------- 43	44 --------- 56	57 --- 87	88
"ME" Bit #	1 ------- 5	6 -------- 8	9 --------- 11	12 --------- 24	25 – 55	56
Field Name	TYPE=28 [5]	Subtype=1 [3]	Emergency/ Priority Status [3]	Mode A Code [13]	Reserved [44]	IMF [1]
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	

Figure 2.2.18.4.5: ADS-R Aircraft Emergency/Priority Status Message Format

2.2.18.4.6 ADS-R Target State and Status Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Target State and Status Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2.2.18.4.6.

Note: *The format is identical to the ADS-B Target State and Status Message depicted in Figure 2-10, except that ME bit 51 is redefined to be the ICAO/Mode A Flag (IMF).*

ADS-R Target State and Status Message					
Msg Bit #	33 ----------- 37	38 ----- 39	40 ----------- 82	83	84 ------ 88
"ME" Bit #	1 -------------- 5	6 -------- 7	8 ------------- 50	51	52 ------ 56
Field Name	**TYPE Code = 29 (11101) [5]**	**Subtype Code=1 (01) [2]**	**Intent/Status Information [43]**	**IMF [1]**	**Intent/Status Information [5]**
	MSB LSB	MSB LSB	MSB LSB		MSB LSB

Figure 2.2.18.4.6: ADS-R "Target State and Status" Message Format

2.2.18.4.7 ADS-R Aircraft Operational Status Messages

The ADS-B Receiving Subsystem **shall** decode and process the ME Field of the ADS-R Aircraft Operational Status Messages, and update and maintain ADS-R Reports with the decoded data in accordance with §2.2.18.5. The format is as specified in Figure 2.2.18.4.7.

Note: *The format is identical to the ADS-B Aircraft Operational Status Message depicted in Figure 2-11, except that ME bit 56 is redefined to be the ICAO/Mode A Flag (IMF).*

ADS-R Aircraft Operational Status Message "ME" Field Format														
Msg BIT #	33 - 37	38 - 40	41 - 52	53 - 56	57 - 72	73 - 75	76	77 - 80	81 - 82	83 - 84	85	86	87	88
"ME" BIT #	1 - 5	6 - 8	9 - 20	21 - 24	25 - 40	41 - 43	44	45 - 48	49 - 50	51 - 52	53	54	55	56
Field Name	**TYPE=31 [5]**	**Subtype=0 [3]**	**Capability Class (CC) Codes [16]**		**Operational Mode (OM) Codes [16]**	**MOPS Version Number [3]**	**NIC Supp. [1]**	**NAC_P [4]**	**GVA [2]**	**Source Integrity Level (SIL) [2]**	**NIC_{BARO} [1]**	**HRD [1]**	**SIL Supp [1]**	**IMF [1]**
		Subtype=1 [3]	**CC Codes [12]**	**L/W Codes [4]**					**Reserved [2]**		**TRK/HDG [1]**			
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB		MSB LSB	MSB LSB	MSB LSB				

Note: *Subfields that are relevant only for Airborne Participants are allocated to Subtype ZERO (binary 000), while those that pertain only to Surface Participants are allocated to Subtype ONE (binary 001).*

Figure 2.2.18.4.7: ADS-R Aircraft Operational Status Message "ME" Field Format

2.2.18.5 ADS-R Report Processing

ADS-R Reports **shall** be maintained and output for DF=18, with CF=4 ADS-R Messages consistent with the ADS-B Report Characteristics requirements of §2.2.8 and the Report Assembly and Delivery requirements of §2.2.10. ADS-R Reports **shall** be provided for both ADS-B Version ONE (1) and Version TWO (2) formatted ADS-R Messages in accordance with the message formats provided in §2.2.18.4.

Note: *ADS-R Reports are for Participants that do not have ADS-B Reports since they are ADS-B Messages transmitted by the Ground for aircraft/vehicles that transmit on a different ADS-B link (e.g., UAT). ADS-R Messages are processed by the 1090ES ADS-B Receiving Subsystems in the same manner as ADS-B Messages received directly from aircraft/vehicle Participants.*

2.3 Equipment Performance - Environmental Conditions

The environmental tests and performance requirements described in this subsection provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual aeronautical operations.

Some of the environmental tests contained in this subsection need not be performed unless the manufacturer wishes to qualify the equipment for that particular environmental condition. These tests are identified by the phrase "When Required." If the manufacturer wishes to qualify the equipment to these additional environmental conditions, then these "when required" tests **shall** be performed.

The test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA DO-160F (EUROCAE ED-14F), Environmental Conditions and Test Procedures for Airborne Equipment, July 1997.

Some of the performance requirements in Subsections 2.1 and 2.2 are not tested by test procedures herein. Moreover, not all tests are required to be done at each of the environmental conditions in RTCA DO-160F (EUROCAE ED-14F). Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Subsections 2.1 and 2.2 will not be measurably degraded by exposure to these environmental conditions.

The specified performance tests cover all classes of ADS-B Transmitting and Receiving Subsystems. Only those tests that are applicable to the class of equipment being qualified need be performed. Additional tests may have to be performed in order to determine performance of particular design requirements that are not specified in this document. It is the responsibility of the manufacturer to determine appropriate tests for these functions.

Specific ADS-B Transmitting and Receiving Subsystem performance tests have been included in this section for use in conjunction with the environmental procedures of RTCA DO-160F (EUROCAE ED-14F). These tests have been chosen as a subset of the ADS-B Transmitting and Receiving Subsystem performance tests provided in subsection

2.4. Normally, a MOPS document does not provide specific equipment performance tests to be used in conjunction with the environmental procedures of RTCA DO-160F (EUROCAE ED-14F). However, there is a sufficiently large number of ADS-B Transmitting and Receiving Subsystem performance tests in subsection 2.4 that it would be impractical to repeat all of those tests in conjunction with all of the appropriate environmental procedures.

2.3.1 Environmental Test Conditions

Table 2-108 lists all of the environmental conditions and test procedures (hereafter referred to as environmental procedures) that are documented in RTCA DO-160F (EUROCAE ED-14F). Table 2-109 lists the sets of ADS-B Transmitting and Receiving Subsystem performance tests that are specified in detail in this section and which are intended to be run subject to the various environmental procedures of RTCA DO-160F (EUROCAE ED-14F). In order to simplify the process of relating the environmental procedures to the ADS-B equipment performance tests, Table 2-108 divides the environmental procedures into groups. All of the procedures in a given group are carried out in conjunction with the same set of ADS-B Transmitting and Receiving Subsystem performance tests. Using this approach, the environmental procedures fall into five groups. The environmental procedures that apply to all of the sets of ADS-B Transmitting and Receiving Subsystem tests fall into group 1. Group 2 procedures apply to 9 of the sets of ADS-B Transmitting and Receiving Subsystem performance tests. Group 3 procedures apply to 6 of the sets of ADS-B Transmitting and Receiving Subsystem performance tests. Group 4 procedures apply to one set of the performance tests. Group 5, which applies to none of the ADS-B Transmitting and Receiving Subsystem performance tests, includes only environmental procedures that are intended to determine the effect of the ADS-B Transmitting and/or Receiving Subsystem on rack mounting hardware, compass needles, explosive gases, and other RF hardware.

Table 2-109 indicates which of the groups of environmental procedures is related to each set of ADS-B Transmitting and/or Receiving Subsystem performance tests. Each ADS-B Transmitting and/or Receiving Subsystem performance test **shall** be validated under all of the environmental procedures in the groups required for that test as indicated in Table 2-109.

Table 2-108: Environmental Test Groups

TEST #	ENVIRONMENTAL CONDITION	RTCA DO-160F Paragraph	EUROCAE ED-14F Paragraph	GROUPS	REMARKS
4a	Temperature	4.5	4.4 – 4.5	1	
4b	Altitude	4.6.1	4.6.1	3	
4c	Decompression & Overpressure	4.6.2 - 4.6.3	4.6.2 - 4.6.3	3	
5	Temperature Variation	5.0	5.0	3	
6	Humidity	6.0	6.0	2	
7a	Operational Shock	7.2	7.1	2	
7b	Crash Safety	7.3	7.2	5	NO TESTS
8	Vibration	8.0	8.0	3 & 1	3 during: 1 after
9	Explosion	9.0	9.0	5	NO TESTS
10	Waterproofness	10.0	10.0	2	
11	Fluids Susceptibility	11.0	11.0	2	
12	Sand and Dust	12.0	12.0	2	
13	Fungus Resistance	13.0	13.0	2	
14	Salt Spray	14.0	14.0	2	
15	Magnetic Effect	15.0	15.0	5	NO TESTS
16	Power Input Momentary Interruptions All Others	16.0	16.0	4 3 & 2	3 during: 2 after
17	Voltage Spike	17.0	17.0	2	
18	Audio Frequency Conducted Susceptibility	18.0	18.0	1	
19	Induced Signal Susceptibility	19.0	19.0	1	
20	RF Susceptibility	20.0	20.0	1	
21	Emission of RF Energy	21.1	21.1	5	NO TESTS
22	Lightning Induced Transient Susceptibility	22.0	22.0	3	
23	Lightning Direct Effects	23.0	23.0	3	
24	Icing	24.0	24.0	2	
25	Electrostatic Discharge	25.0	25.0		NO TESTS

Notes to Table 2-108:

1. *Tests in Group 5 determine the effects of the ADS-B equipment on other equipment (mounts, compass needles, explosive gases, and other RF equipment) and therefore do not involve the ADS-B equipment performance requirements of this document.*

2. *Environmental test conditions specified in these MOPS are not directly applicable to non-aircraft installations. Manufacturers of such equipment may be permitted to substitute appropriate test standards, such as SAE J1455 (Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy Duty Trucks)).*

Table 2-109: Performance Test Requirements During Environmental Tests

Test Procedure Paragraph	DESCRIPTION	Required Environmental Test Groups (See Table 2-108)				
		1	**2**	**3**	**4**	**5**
§2.3.2.1	Transponder-Based Transmitters	X	X	X		
§2.3.2.2	Stand Alone (Non-Transponder-Based) Transmitters	NT	NT	NT	NT	NT
§2.3.2.2.1	Frequency	X	X	X		
§2.3.2.2.2	Pulse Shapes	X				
§2.3.2.2.3	Pulse Interval	X				
§2.3.2.2.4	Preamble	X				
§2.3.2.2.5	Data Pulses	X		X		
§2.3.2.2.6	RF Peak Output Power	NT	NT	NT	NT	NT
§2.3.2.2.6.1	Class A0 Equipment RF Peak Output Power	X	X			
§2.3.2.2.6.2	Class B Equipment RF Peak Output Power	X	X			
§2.3.2.2.7	Transmission Rates for Transponder - Based Transmitters	NT	NT	NT	NT	NT
§2.3.2.2.7.1	Transmission Rates Compliant with RTCA DO-181D	X	X			
§2.3.2.2.7.2	Transmission Rates not specified in RTCA DO-181D	X	X			
§2.3.2.2.7.3	Maximum Transmission Rates for Transponder - Based Transmitters	X	X			
§2.3.2.2.8	Transmission Rates for Stand Alone Transmitters	X	X			
§2.3.2.2.8.1	Power-On Initialization	X	X			
§2.3.2.2.8.2	ADS-B Airborne Position Message Broadcast Rate	X				
§2.3.2.2.8.3	ADS-B Surface Position Message Broadcast Rate	X				
§2.3.2.2.8.4	ADS-B Aircraft Identification and Category Message Broadcast Rate	X				
§2.3.2.2.8.5	ADS-B Velocity Information Message Broadcast Rate	X				
§2.3.2.2.8.6	ADS-B Aircraft Target State and AStatus Message Broadcast Rates	X				
§2.3.2.2.8.7	ADS-B Aircraft Operational Status Message Broadcast Rates	X				
§2.3.2.2.8.8	"Extended Squitter Aircraft Status" ADS-B Message Broadcast Rate	X				
§2.3.2.2.8.9	"TYPE 23 (TEST)" ADS-B Message Broadcast Rate	X				
§2.3.2.2.8.10	Maximum ADS-B Message Transmission Rates	X				
§2.3.2.3	Receivers Shared with a TCAS Unit	X	X	X		
§2.3.2.3.1	TCAS Compatibility	X				
§2.3.2.3.2	Re-Triggerable Reply Processor	X	X			
§2.3.2.3.3	Verfication of Enhanced Squitter Reception Techniques (§2.2.4.4)	NT	NT	NT	NT	NT
§2.3.2.3.3.1	Combined Preamble and Data Block Tests with A/C Fruit	X				
§2.3.2.3.3.2	Data Block Tests with Mode S Fruit	X				
§2.3.2.3.3.3	Re-Triggering Performance	X				
§2.3.2.4	Receivers Not Shared with TCAS (§2.2.4.3)	NT	NT	NT	NT	NT
§2.3.2.4.1	In-Band Acceptance	X	X	X		
§2.3.2.4.2	Dynamic Range	X	X	X		
§2.3.2.4.3	Re-Triggerable Capability	X	X			
§2.3.2.4.4	Out-of-Band Rejection	X	X			
§2.3.2.4.5	Dynamic Minimum Trigger Level	X	X			
§2.3.2.4.6	Criteria for ADS-B Message Transmission Pulse Detection	X				
§2.3.2.4.7	Criteria for Data Block Acceptance in ADS-B Message Signals	X				
§2.3.2.4.8	Verification of Enhanced Squitter Reception Techniques (§2.2.4.4)	NT	NT	NT	NT	NT
§2.3.2.4.8.1	Combined Preamble and Data Block Tests with A/C Fruit	X				
§2.3.2.4.8.2	Data Block Tests with Mode S Fruit	X				
§2.3.2.4.8.3	Re-Triggering Performance	X	X	X		

Table 2-109: Performance Test Requirements During Environmental Tests (Continued)

Test Procedure Paragraph	DESCRIPTION	Required Environmental Test Groups (See Table 2-108)				
		1	2	3	4	5
§2.3.2.4.9	Track File Maintenance	X	X	X		
§2.3.2.5	Self Test and Monitors	NT	NT	NT	NT	NT
§2.3.2.5.1	Transponder-Based Equipment Address	X	X	X	X	
§2.3.2.5.2	Non-Transponder-Based Equipment	X	X	X	X	
§2.3.2.6	Response to Mutual Suppression	NT	NT	NT	NT	NT
§2.3.2.6.1	Transmitting Device Response to Mutual Suppression Pulses	X				
§2.3.2.6.2	Receiving Device Response to Mutual Suppression Pulses	X				
§2.3.2.7.1	Transmitting Diversity	X	X			
§2.3.2.7.2	Receiving Diversity	NT	NT	NT	NT	NT
§2.3.2.7.2.1	Full Receiver and Message Processing or Receiver Switching Front-End Diversity	X	X			
§2.3.2.7.2.2	Receiving Antenna Switching Diversity	X	X			
§2.3.2.8	Power Interruption	NT	NT	NT	NT	NT
§2.3.2.8.1	Power Interruption to ADS-B Transmitting Subsystems	X			X	
§2.3.2.8.2	Power Interruption to ADS-B Receiving Subsystems	X			X	
§2.3.2.9	Verification of Traffic Information Services – Broadcast (TIS-B)	NT	NT	NT	NT	NT
§2.3.2.9.1	Verification of TIS-B Report Generation	X				

Note: *"NT" in the above table means "NO TEST."*

2.3.2 Detailed Environmental Test Procedures

The test procedures set forth below are considered satisfactory for use in determining equipment performance under environmental conditions. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternative procedures may be used if the manufacturer can show that they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternative procedures. The ADS-B Transmitting and Receiving Subsystem performance tests do not include specific pass/fail criteria. It is intended that those criteria be obtained from the ADS-B Transmitting and Receiving performance requirements provided in subsection 2.2.

2.3.2.1 Transponder-Based Transmitters (§2.2.2.1)

Transponder-Based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.3.2.2 inclusive (EUROCAE ED-73C, chapter 4).

2.3.2.2 Stand Alone (Non-Transponder-Based) Transmitters (§2.2.2.2)

No specific test procedure is required to validate §2.2.2.2.

2.3.2.2.1 Frequency (§2.2.2.2.1)

Equipment Required:

Provide equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test through the operational interface. Provide a Stub Tuner (Microlab/FXR Sl-05N, or equivalent). Provide a Variable Air Line (Line Stretcher) (Microlab/FKR SR-05N, or equivalent). Provide a Slotted Line (HP 805C, or equivalent).

Measurement Procedure:

Determine the transmission frequency

Load valid data into the ADS-B Airborne Position format and ensure that the expected ADS-B transmissions occur. Adjust the stub to establish a l.5:l VSWR at the antenna end of the coax line specified by the manufacturer. If the ADS-B transmitter requires a minimum length of a specified cable type, an attenuator equal to the loss of the minimum amount of cable may be placed between the 1.5:1 VSWR point and the equipment antenna jack. Alternately, a length of cable equal to the specified minimum length and cable type may be used in lieu of the attenuator. Adjust the line stretcher for maximum transmitter frequency shift above and below 1090 MHz. Determine that the frequency shift does not exceed the requirements of §2.2.2.2.1.

2.3.2.2.2 Pulse Shapes (§2.2.2.2.4)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B broadcast message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Step 1: ADS-B Message Pulse Amplitude Variation (§2.2.3.1.3.a)

Load valid data into the ADS-B Airborne Position Message and verify that the messages are being transmitted by the equipment under test. Measure the maximum power differential between pulses in ADS-B broadcast messages. Verify that it is within the tolerance specified in §2.2.3.1.3.a.

Step 2: ADS-B Message Pulse Shape (§2.2.3.1.3.b and c)

Load valid data into the ADS-B Airborne Position Message and verify that the messages are being transmitted by the equipment under test. Measure the rise and decay time of the ADS-B broadcast message pulses. Verify that they are within the tolerances specified in §2.2.3.1.3.b and c.

Note: *Pulse Rise Time is measured as the time interval between 10 percent and 90 percent of peak amplitude on the leading edge of the pulse. Pulse Decay Time is measured as the time interval between 90 percent and 10 percent of peak amplitude on the tailing edge of the pulse. See "Caution" statement below.*

CAUTION: *If the detector is not known to be linear, checks should be made to determine what amplitude points on the detected pulse correspond to the 10 percent and 90 percent amplitude points of the RF pulses. In addition, checks should be made to determine the rise and decay time of the detector.*

2.3.2.2.3 Pulse Interval (§2.2.2.2.6)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

ADS-B Message Pulse Spacing Tolerance (§2.2.3.1.4)

Load valid data into the ADS-B Airborne Position Message and verify that the messages are being output. Determine that the leading edge of any reply pulse is within 50 nanoseconds of its assigned position.

Note: *Interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector. If the detector is not known to be linear, a check should be made to determine the half voltage points.*

2.3.2.2.4 Preamble (§2.2.2.2.7)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Determine Preamble Pulse Spacing

Load valid data into the ADS-B Airborne Position Message and verify that the messages are being transmitted by the equipment under test. Display the ADS-B Messages on the oscilloscope. Measure the pulse duration of the first four message pulses. Measure the pulse spacing between the leading edge of the first and each of the second, third, and fourth pulses. Determine that the spacing of the pulses is within the tolerances specified in §2.2.3.1.1.

Note: *Interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector. If the detector is not known to be linear, a check should be made to determine the half voltage points.*

2.3.2.2.5 Data Pulses (§2.2.2.2.8)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Determine Message Data Pulse Width and Duration

Note 1: *For tests in this section, unless otherwise specified, examine pulses at the beginning, middle and end of the ADS-B broadcast messages.*

Load valid data into the ADS-B Airborne Position Message and verify that the messages are being transmitted by the equipment under test. Measure the pulse duration of the pulses transmitted in the ADS-B Message throughout the message transmission. Determine that the duration of the pulses is within the tolerance specified in §2.2.3.1.2.

Measure the pulse spacing of the fifth reply pulse with reference to the first reply pulse. Determine that the pulse spacing is within the tolerance specified in §2.2.3.1.2.

Note 2: *Interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector. If the detector is not known to be linear, a check should be made to determine the half voltage points.*

2.3.2.2.6 RF Peak Output Power (§2.2.2.2.10)

No specific test procedure is required to validate §2.2.2.2.10.

2.3.2.2.6.1 Class A0 Equipment RF Peak Output Power (§2.2.2.2.10.1)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Load valid data into the ADS-B Airborne Position format and ensure that the expected ADS-B transmissions occur. Measure the single pulse having the maximum RF power output. Determine that the maximum power output meets the requirements of §2.2.2.2.10.1.

2.3.2.2.6.2 Class B Equipment RF Peak Output Power (§2.2.2.2.10.2)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Load valid data into the ADS-B Airborne Position format and ensure that the expected ADS-B transmissions occur. Measure the single pulse having the maximum RF power output. Determine that the maximum power output meets the requirements of §2.2.2.2.10.2.

2.3.2.2.7 Transmission Rates for Transponder - Based Transmitters (§2.2.3.3.1)

No specific test procedure is required to validate §2.2.3.3.1.

2.3.2.2.7.1 Transmission Rates Compliant with RTCA DO-181D (§2.2.3.3.1.1)

Performance of ADS-B transmitters based on Mode S transponders **shall** validate Message Transmit Rates in accordance with RTCA DO-181D §2.5.4.6.2 (EUROCAE ED-73C, §5.5.8.6.2), for each class of transponder defined in the latest version of FAA TSO-C112.

2.3.2.2.7.2 Transmission Rates Not Specified in RTCA DO-181D (§2.2.3.3.1.2) (EUROCAE ED-73C)

When the transmission rate of a particular message type is not specified or is not tested in RTCA DO-181D (EUROCAE ED-73C), then the Mode S Transponder-Based ADS-B transmitters **shall** verify the message delivery performance for those messages in accordance with §2.3.2.2.8 through §2.3.2.2.8.10 of this document for Stand Alone Transmitters. If there is conflict between the requirements of RTCA DO-181D (EUROCAE ED-73C) and this document, then the requirements of RTCA DO-181D (EUROCAE ED-73C) **shall** be adhered to.

2.3.2.2.7.3 Maximum Transmission Rates for Transponder-Based Transmitters (§2.2.3.3.1.3)

Performance of ADS-B transmitters based on Mode S transponders **shall** validate maximum transmission rates in accordance with RTCA DO-181D (EUROCAE ED-73C), for each class of transponder defined in the latest version of FAA TSO-C112.

When the maximum transmission rate of a particular message type is not specified or is not tested in RTCA DO-181D (EUROCAE ED-73C), then the Mode S Transponder-Based ADS-B transmitters **shall** verify the maximum message delivery rate in accordance with §2.3.2.2.8.10 of this document for Stand Alone transmitters. If there is conflict between the requirements of RTCA DO-181D (EUROCAE ED-73C) and this document, then the requirements of RTCA DO-181D (EUROCAE ED-73C) **shall** be adhered to.

2.3.2.2.8 Transmission Rates for Stand Alone Transmitters (§2.2.3.3.1.4)

Purpose/Introduction:

a. Stand Alone Transmitters for Class A0 and Class B0 equipment are those implemented independent of a Mode S transponder. Such transmitters **shall** meet the transmission rate requirements of §2.2.3.3.1.3 and the message update rate requirements specified in the following subparagraphs.

b. Add a quantization interval for the transmitted message jitter of 15 milliseconds or less.

Equipment Required:

Provide a method of loading valid data for the generation of ADS-B Airborne Position, Surface Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status broadcast messages into the ADS-B Transmitting Subsystem under test.

Provide a method of recording and time stamping all ADS-B Broadcast messages transmitted by the ADS-B Transmitting Subsystem under test with the time stamping quantization being 15 milliseconds or less.

Measurement Procedure:

Step 1: ADS-B Message Broadcast Setup

Provide the ADS-B Transmitting Subsystem under test with all valid necessary data for the generation of ADS-B Airborne Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status broadcast messages.

Verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Messages.

Step 2: ADS-B Message Recording and Time Stamping

Record and time stamp all ADS-B Messages that are broadcast by the ADS-B Transmitting Subsystem for a period of not less than 5 minutes.

Step 3: Distribution Checks

For each of the ADS-B Airborne Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status Message types transmitted, verify that the messages are distributed over the specified range of transmission intervals for each particular message type.

Step 4: Interval Quantization Checks

For each of the ADS-B Airborne Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status Message types transmitted, verify that the messages were distributed with the jitter spacing being 15 milliseconds or less between messages of equivalent type.

2.3.2.2.8.1 Power-On Initialization (§2.2.3.3.2.1.1)

Equipment Required

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure

Step 1: No Data Available (§2.2.3.3.2.1.1.a)

Ensure that no appropriate valid message data are available for any of the possible ADS-B broadcast messages. Power up the equipment. Verify that no transmissions occur.

Step 2: Valid Data available (§2.2.3.3.2.1.1.b)

For each ADS-B Position and Velocity Message type in turn, ensure that appropriate valid ADS-B Message data are available for that message type only. Power up the equipment. Verify that the correct ADS-B broadcast message is transmitted starting no later than 2.0 seconds after Power-On.

2.3.2.2.8.2 ADS-B Airborne Position Message Broadcast Rate (§2.2.3.3.2.2)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope, or equivalent method of observing the message content.

Measurement Procedure:

Ensure that the equipment is set to the "Airborne" condition and that the appropriate valid ADS-B Airborne Position data is available. Verify that the ADS-B Airborne Position Message is broadcast at intervals that are distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.2.

2.3.2.2.8.3 ADS-B Surface Position Message Broadcast Rate (§2.2.3.3.2.3)

Equipment Required:

Provide a method of loading valid data for broadcasting ADS-B Messages into the ADS-B equipment under test. Provide a method of monitoring the transmitted ADS-B Messages and measuring the rate at which they are output.

Measurement Procedure:

Step 1: Switching from High Rate to Low Rate (§2.2.3.3.2.3.a(1) and c)

Ensure that the equipment is set to the "On the Ground" condition and that the appropriate valid ADS-B Surface Position data is provided such that the position is changing at a rate of 10.1 meters in any 30 second interval. At least 61 seconds after the start of the data input, verify that the ADS-B Surface Position Message is broadcast at intervals that are distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.3.b.

Input new ADS-B Surface Position data with the position data changing at a rate of 9.9 meters in any 30 second interval. At least 61 seconds after the inputting of the new data, verify that the ADS-B Surface Position Message is broadcast at intervals that are distributed over the range of 4.8 to 5.2 seconds as specified in §2.2.3.3.2.3.c.

Step 2: Switching from Low Rate to High Rate (§2.2.3.3.2.3.a(2) and c)

Ensure that the equipment is set to the "On the Ground" condition and that the appropriate valid ADS-B Surface Position data is provided such that the position is stationary. At least 61 seconds after establishing the data, verify that the ADS-B Surface Position Messages are broadcast at intervals that are distributed over the range of 4.8 to 5.2 seconds as specified in 2.2.3.3.2.3.c.

Input new ADS-B Surface Position data such that the position is stationary and 10.1 meters away from the position above. One (1) second after inputting the new data, verify that the ADS-B Surface Position Messages are broadcast at intervals that are distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.3.b. Also verify that at least 61 seconds after establishing the new data that the ADS-B Surface Position Message is broadcast at intervals that are distributed over the range 4.8 to 5.2 seconds as specified in §2.2.3.3.2.3.c.

2.3.2.2.8.4 ADS-B Aircraft Identification and Category Message Broadcast Rate (§2.2.3.3.2.4)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: Airborne (§2.2.3.3.2.4.a)

Ensure that the equipment is set to the "Airborne" condition and that the appropriate valid ADS-B Aircraft Identification and Category data is available. Verify that the ADS-B Aircraft Identification and Category message is broadcast at intervals that are distributed over the range of 4.8 to 5.2 seconds as specified in §2.2.3.3.2.4.a.

Step 2: On the Ground (§2.2.3.3.2.4.b)

Ensure that the equipment is set to the "On the Ground" condition and that the appropriate valid ADS-B Aircraft Identification and Category data is available. Verify that the ADS-B Aircraft Identification and Category Message is broadcast at intervals that are distributed over the range of 9.8 to 10.2 seconds as specified in §2.2.3.3.2.4.b.

2.3.2.2.8.5 ADS-B Velocity Information Message Broadcast Rate (§2.2.3.3.2.5)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Ensure that the appropriate valid ADS-B Velocity Information data is available. Verify that the ADS-B Velocity Information message is broadcast at intervals that are distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.5.a.

2.3.2.2.8.6 Target State and Status Message Broadcast Rates (§2.2.3.3.2.6.1)

Equipment Required:

Provide a Method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Ensure that no Target State data is available. Verify that no Target State and Status Message is output for a period of 20 seconds. Inject the appropriate valid ADS-B Target State data and verify that the ADS-B Target State and Status Message is broadcast at intervals that are distributed over the range of 1.2 to 1.3 seconds as specified in §2.2.3.3.2.6.1.b for as long and data is available.

Repeat the procedure for each Target State and Status Message independently as necessary.

2.3.2.2.8.7 ADS-B Aircraft Operational Status Message Broadcast Rates (§2.2.3.3.2.6.2)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Ensure that no Aircraft Operational Status data is available. Verify that no Aircraft Operational Status Message is output for a period of 20 seconds. Inject the appropriate valid ADS-B Aircraft Operational Status data. Verify that the ADS-B Aircraft Operational Status Message is broadcast at intervals that are distributed over the range of 2.4 to 2.6 seconds as specified in §2.2.3.3.2.6.2.b for a period of 24 ±1 seconds if Target State and Status Messages are being broadcast. Verify that the ADS-B Aircraft Operational Status Message is broadcast at intervals that are distributed over the range of 0.7 to 0.8 seconds as specified in §2.2.3.3.2.6.2.b for a period of 24 ±1 seconds if Target State and Status Messages are not being broadcast.

2.3.2.2.8.8 "Extended Squitter Aircraft Status" ADS-B Message Broadcast Rate (§2.2.3.3.2.6.3)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Establish the emergency condition in accordance with Appendix A., Figure A.8-9, Note 2. Verify that the Emergency/Status Message (TYPE-28, Subtype=1) is broadcast at intervals that are distributed over the range of 0.7 to 0.8 seconds if the Target State and Status Message is not being broadcast. Verify that the Emergency/Status Message (TYPE-28, Subtype=1) is broadcast at intervals that are distributed over the range of 2.4 to 2.6 seconds if the Target State and Status Message is being broadcast. Clear the established emergency condition and verify that NO Emergency/Status Messages are broadcast.

2.3.2.2.8.9 "TYPE 23 (TEST)" ADS-B Message Broadcast Rate (§2.2.3.3.2.7)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Update the TEST ADS-B Message and verify that it is broadcast only once. Repeat 10 times.

2.3.2.2.8.10 Maximum ADS-B Message Transmission Rates (§2.2.3.3.2.10)

Equipment Required:

Provide equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test through the operational interface. Provide a method of monitoring ADS-B broadcast messages output by the equipment under test. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Step 1: Maximum Combined ADS-B Message Output rate (§2.2.3.3.2.10--Airborne

Set the Airborne condition and load valid data into all the ADS-B Broadcast messages that can be supported by the equipment under test at a rate ensuring maximum transmission rate. Also ensure that the data for all event driven messages changes at a rate requiring more than the permitted maximum output rate of two messages per second. Verify that each of the ADS-B Broadcast messages types are output at rates within the specified tolerance, that the Airborne Position Messages are being transmitted, and that only two event driven messages per second are transmitted. Also verify that the total combined rate is less than or equal to 6.2 messages per second.

During this test, also verify that the transmitted output power remains within the specified limits.

2.3.2.3 Receivers Shared with a TCAS Unit (§2.2.4.2)

ADS-B receivers implemented as part of a TCAS unit **shall** demonstrate compliance with Test Procedures specified in the TCAS MOPS, RTCA DO-185B, §2.4.2.1.2 (EUROCAE ED-143, §2.4.2.1.2).

In addition to tests specified in the TCAS MOPS, RTCA DO-185B, §2.4.2.1.2 (EUROCAE ED-143, §2.4.2.1.2), TCAS units operating with receivers that are more sensitive than the MTL requirements specified in RTCA DO-185B (EUROCAE ED-143), **shall** be submitted to the following test procedures provided through §2.3.2.4.7.

2.3.2.3.1 TCAS Compatibility (§2.2.4.2.1.1)

Purpose/Introduction:

This test verifies that no more than 10% of ADS-B Messages received at a level of –78 dBm or below **shall** be passed to the TCAS surveillance function.

Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-78 dBm

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B **Input** Message

Apply **Input** at the receiver input port.

Step 2: Verify ADS-B **Input** Message Reception

Verify that no more than 10% of all ADS-B Messages are passed on to the TCAS surveillance function.

Step 3: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 and 2 on all other applicable receiver RF input ports of the UUT.

2.3.2.3.2 Re-Triggerable Reply Processor (§2.2.4.2.2)

Purpose/Introduction:

The following procedures verify the capability of the TCAS shared ADS-B receiver to detect overlapping Mode-S replies or ADS-B Messages in the TCAS level range.

Inputs:

All Intruder Aircraft:

Frequency = 1090 MHz.
Altitude Rate = 0 FPM

Intruder Aircraft 1:

Equipage	=	Mode-S ADS-B
Squitter Power	=	-50 dBm
Altitude	=	8000 ft.
Range	=	2 NM at T=0 sec.

Intruder Aircraft 2:

Equipage	=	Mode-S ADS-B
Squitter Power	=	-44 dBm
Altitude	=	8000 ft.
Range	=	Maintained such that the leading edge of the first preamble pulse from Intruder 2 occurs 12 ±1.0 µs later than the leading edge of the first preamble pulse from Intruder 1 throughout the scenario.

TCAS Aircraft:

Altitude	=	8000 ft.
Altitude Rate	=	0 FPM
Range	=	0 NM
Sensitivity Level Selection	=	Automatic

ADS-B Message Format (Intruder 1):

All ADS-B Message transmissions **shall** have the following standard data field values:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address

Mode-S Squitter Format (Intruder 2):

All Mode-S squitter transmissions **shall** have the following standard data field values:

"DF"	=	11
"CA"	=	0
"AA"	=	Any discrete address

Conditions:

TCAS initialized and operating at T = 0 seconds. Intruders 1 and 2 **shall** each transmit squitters during the squitter listening period following each whisper-shout sequence and **shall** reply with a short special surveillance format (DF=0) to each TCAS discrete interrogation.

Scenario Description:

Both Intruders are co-altitude with TCAS and each transmits squitters when TCAS is in squitter listening mode and replies to discrete interrogations from TCAS. Intruder 2 is overlapping the Intruder 1 reply window.

Measurement Procedure:

The receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B and Mode-S Input Messages

Apply the message inputs specified above to the receiver input port.

Verify that the TCAS receiver detects intruder #2.

Step 2: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 on all other applicable receiver RF input ports of the UUT.

Step 3: Vary Signal Power Levels

Repeat Steps 1 and 2 with the following additional squitter power levels:

a. Intruder Aircraft 1 – Squitter Power = -30 dBm

Intruder Aircraft 2 – Squitter Power = -24 dBm

b. Intruder Aircraft 1 – Squitter Power = MTL + 3 dB

Intruder Aircraft 2 – Squitter Power = MTL + 9 dB

Verify that the TCAS receiver detects Intruder Aircraft #2 for each case.

2.3.2.3.3 Verification of Enhanced Squitter Reception Techniques (§2.2.4.4)

No specific test procedures are required to validate §2.3.2.3.3.

The following test procedures apply to Class A1S, A1, A2 and A3 receivers that implement Enhanced Squitter Reception Techniques and are part of the TCAS Receiver.

2.3.2.3.3.1 Combined Preamble and Data Block Tests with A/C Fruit

Perform the test procedures provided in §2.3.2.4.8.1.

2.3.2.3.3.2 Data Block Tests with Mode S Fruit

Perform the test procedures provided in §2.3.2.4.8.2.

2.3.2.3.3.3 Re-Triggering Performance

Perform the test procedures provided in §2.3.2.4.8.3.

2.3.2.4 Receivers Not Shared With TCAS (§2.2.4.3)

No specific test procedure is required to validate §2.2.4.3.

2.3.2.4.1 In-Band Acceptance (§2.2.4.3.1.1.a)

Purpose/Introduction:

This test verifies the compliance of the ADS-B receiver with the sensitivity requirements specified for the particular ADS-B equipage class.

Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-68 dBm

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages

Apply **Input** at the receiver input port.

Step 2: Establish UUT Receiver MTL

Decrease the input power level and determine the minimum RF signal level required to produce a 90 percent ADS-B Message reception rate by the UUT receiver.

This value plus the loss line value represents the measured MTL of the UUT ADS-B receiver.

Verify that the measured MTL is in compliance with the limits specified in §2.2.4.3.1.1.a for the UUT equipment class.

Step 3: Verify UUT Receiver MTL over the Operational Frequency Range

Vary the RF signal frequency over the range of 1089 to 1091 MHz and determine the variation in RF signal level required to produce 90 percent ADS-B Message reception rate by the UUT receiver.

Verify that the measured MTL continues to comply with the limits specified in §2.2.4.3.1.1.a for the UUT equipment class.

Step 4: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.3.2.4.2 Dynamic Range (§2.2.4.3.1.1.b)

Purpose/Introduction:

This test verifies that the ADS-B receiver can detect and decode valid ADS-B Messages over the equipment's specified dynamic range.

Input:

Equipment:

Provide a method of providing the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-68 dBm

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages

Apply **Input** at the receiver input port.

Step 2: Establish UUT Receiver MTL

Decrease the input power level and determine the minimum RF signal level required to produce 90 percent ADS-B Message reception rate by the UUT receiver. This value plus the loss line value represents the measured MTL of the UUT ADS-B receiver.

Step 3: Verify UUT Receiver Dynamic Range

Increase the input signal power level to MTL + 3 dB. Verify that the receiver properly detects and decodes at least 99% of all ADS-B Messages received. Increase the input signal power level in 10 dB steps up to a signal level of -21 dBm. At each step, verify that the receiver properly detects and decodes at least 99% of all ADS-B Messages received.

Step 4: Verify Class A3 UUT Receiver Performance

Decrease the input signal power level to –87 dBm. Verify that the receiver properly detects and decodes at least 15% of all ADS-B Messages input.

Step 5: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.3.2.4.3 Re-Triggerable Capability (§2.2.4.3.1.2)

Purpose/Introduction:

The following procedures verify the capability of the Stand alone ADS-B receiver to detect overlapping ADS-B broadcast messages.

Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-50 dBm

Followed by a second Valid Mode S Extended Squitter:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address different from the first one
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-42 dBm

Starting 6.0 ±1.0 µsec later than the leading edge of the first ADS-B Message.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Re-Trigger Capability - Part 1

Apply **Input** at the receiver input and verify that at least the reply ratio in the following table of the second valid ADS-B Messages are correctly decoded.

Receiver Class	**Class A1S/A1**	**Class A2**	**Class A3**
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93

Step 2: Re-Trigger Capability - Part 2

Repeat Step 1 with the **Input** signal power level at MTL + 6 dB for the first ADS-B Message and MTL + 14 dB for the second ADS-B Message.

Step 3: Re-Trigger Capability - Part 3

Repeat Step 1 with **Input** level at -32 dBm for the first ADS-B Message and -24 dBm for the second ADS-B Message.

Step 4: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.3.2.4.4 Out-of-Band Rejection (§2.2.4.3.2)

Purpose/Introduction:

This test verifies that the ADS-B out-of-band rejection is in accordance with the specified values.

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	MTL + 3 dB

Where MTL is the measured value of MTL made at 1090 MHz.

Input B:

Same as Input A with:

Frequency	=	1084.5 MHz
Power	=	MTL + 6 dB

Input C:

Same as Input A with:

Frequency	=	1080.0 MHz
Power	=	MTL + 23 dB

Input D:

Same as Input A with:

Frequency	=	1075.0 MHz
Power	=	MTL + 43 dB

Input E:

Same as Input A with:

Frequency	=	1065.0 MHz
Power	=	MTL + 63 dB

Input F:

Same as Input A with:

Frequency	=	1095.5 MHz
Power	=	MTL + 6 dB

Input G:

Same as Input A with:

Frequency	=	1100.0 MHz
Power	=	MTL + 23 dB

Input H:

Same as Input A with:

Frequency	=	1105.0 MHz
Power	=	MTL + 43 dB

Input I:

Same as Input A with:

Frequency	=	1115.0 MHz
Power	=	MTL + 63 dB

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply Initial ADS-B Input Messages

Apply Input B at the receiver input port and decrease the power level until the percentage of decoded ADS-B Messages is less than or equal to 90 percent.

Verify that the measured signal power level required to produce a message decoding percentage of greater than or equal to 90 percent is greater than the limit specified in Table 2-80 in §2.2.4.3.2.

Step 2: Vary the Input Signal Power and Frequency

Repeat Step 1 using inputs C, D, E, F, G, H, and I.

Step 3: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 and 2 on all other applicable receiver RF input ports of the UUT.

2.3.2.4.5 Dynamic Minimum Trigger Level (DMTL) (§2.2.4.3.3)

Purpose/Introduction:

This test verifies that, when DMTL control is implemented (see §2.2.4.3.3), then the ADS-B receiver DMTL is capable of rejecting low level signals during a valid squitter reception and that DMTL is capable of recovering in not more than 128 microseconds after the leading edge of the first preamble pulse of a valid ADS-B Message.

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-61 dBm

Overlapped by a pulse having the following characteristics:

Pulse Width	=	120 ±1 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Frequency	=	1090 MHz
Power	=	-69 dBm

Starting 0.7 ±0.2 μsec after the leading edge of the first preamble pulse of the ADS-B Message.

Input B:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-40 dBm

Overlapped by a pulse having the following characteristics:

Pulse Width	=	120 ±1 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-49 dBm

Starting 0.7 ±0.2 μsec after the leading edge of the first preamble pulse of the ADS-B Message.

Input C:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-21 dBm

Overlapped by a pulse having the following characteristics:

Pulse Width	=	120 ±1 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-30 dBm

Starting 0.7 ±0.2 μsec after the leading edge of the first preamble pulse of the ADS-B Message.

Input D:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-21 dBm

Followed by a second Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-60 dBm

Starting 129 ±1 μsec after the leading edge of the first preamble pulse of the first ADS-B Message.

<u>Input E:</u>

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-70 dBm

Preceded by a pulse having the following characteristics:

Pulse Width	=	0.50 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-60 dBm

Starting 4.0 μsec before the leading edge of the first preamble pulse of the ADS-B Message.

<u>Input F:</u>

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-70 dBm

Preceded by a pulse having the following characteristics:

Pulse Width	=	0.50 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-60 dBm

Starting 9.0 μsec before the leading edge of the first preamble pulse of the ADS-B Message.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: DMTL Desensitization - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the valid ADS-B Messages are correctly decoded.

Step 2: DMTL Desensitization - Part 2

Repeat Step 1 using **Input B**.

Step 3: DMTL Desensitization - Part 3

Repeat Step 1 using **Input C**.

Step 4: DMTL Recovery - Part 4

Apply **Input D** at the receiver input and verify that at least 90 percent of the second valid ADS-B Messages are correctly decoded.

Step 5: DMTL Desensitization after a Single Pulse

Apply **Input E** at the receiver input and verify that no more than 10 percent of the valid ADS-B Messages are correctly decoded.

Step 6: DMTL Recovery after a Single Pulse

Apply **Input F** at the receiver input and verify that at least 90 percent of the valid ADS-B Messages are correctly decoded.

2.3.2.4.6 Criteria for ADS-B Message Transmission Pulse Detection (§2.2.4.3.4.7.1 and §2.2.4.3.4.7.2)

2.3.2.4.6.1 Criteria for ADS-B Message Transmission Pulse Detection for Receivers not using Enhanced Reception Techniques

Purpose/Introduction:

These test procedures verify that the ADS-B reply processor correctly detects the presence of a valid ADS-B preamble whose pulse characteristics are within the allowable limits and rejects preambles having pulse spacing and position characteristics that are outside the allowable limits.

Note: *This test is not applicable to equipment which uses the enhanced reception techniques. That is, it is not applicable to equipage Classes A1S, A1, A2 and A3. The enhanced preamble detection requirements for this equipment are tested in §2.3.2.4.6.2.*

Reference Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-23 dBm (for the first preamble pulse level

Input A:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-110: Input A: Preamble Pulse Characteristics

Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.05	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.05	-0.125	+2
3	0.05 - 0.1	0.05 - 0.2	+0.05	+0.125	+2
4	0.05 - 0.1	0.05 - 0.2	-0.05	-0.125	0

Input B:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-111: Input B: Preamble Pulse Characteristics

Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	-0.3	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
3	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
4	0.05 - 0.1	0.05 - 0.2	-0.3	0	0

Input C:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-112: Input C: Preamble Pulse Characteristics

Pulse	Rise time (μsec)	Fall time (μsec)	Δ Width (μsec)	Δ Position (μsec)	Δ Amplitude (dB)
1	0.05 - 0.1	0.05 - 0.2	0	—	—
2	0.05 - 0.1	0.05 - 0.2	0	+0.2	0
3	0.05 - 0.1	0.05 - 0.2	0	+0.2	0
4	0.05 - 0.1	0.05 - 0.2	0	+0.2	0

Input D:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-113: Input D: Preamble Pulse Characteristics

Pulse	Rise time (μsec)	Fall time (μsec)	Δ Width (μsec)	Δ Position (μsec)	Δ Amplitude (dB)
1	0.05 - 0.1	0.05 - 0.2	+4.5	—	—
2					
3	Pulse Not Present				
4					

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 2: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 2

Repeat Step 1 with the signal power level at -65 dBm.

Step 3: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 1

Apply **Input B** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 4: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 2

Repeat Step 3 with the signal power level at -65 dBm.

Step 5: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 1

Apply **Input C** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 6: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 2

Repeat Step 5 with the signal power level at -65 dBm.

Step 7: Preamble Single Pulse - Part 1

Apply **Input D** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 8: Preamble Single Pulse - Part 2

Repeat Step 7 with the signal power level at -65 dBm.

2.3.2.4.6.2 Criteria for ADS-B Message Transmission Pulse Detection for Receivers using Enhanced Reception Techniques

Purpose/Introduction:

These tests verify that the ADS-B reply processor correctly detects the presence of a valid ADS-B preamble whose pulse characteristics are within the allowable limits and rejects preambles having pulse spacing and position characteristics that are outside the allowable limits.

Reference Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-23 dBm (for the first preamble pulse level

Input A:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-2.3.2.4.6.2A: Input A: Preamble Pulse Characteristics

Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.05	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.05	+0.100	+2
3	0.05 - 0.1	0.05 - 0.2	+0.05	+0.100	+2
4	0.05 - 0.1	0.05 - 0.2	-0.05	+0.100	0

Input B:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-2.3.2.4.6.2B: Input B: Preamble Pulse Characteristics

Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.05	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.05	-0.100	+2
3	0.05 - 0.1	0.05 - 0.2	+0.05	-0.100	+2
4	0.05 - 0.1	0.05 - 0.2	-0.05	-0.100	0

Input C:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-2.3.2.4.6.2C: Input C: Preamble Pulse Characteristics

Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	-0.3	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
3	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
4	0.05 - 0.1	0.05 - 0.2	-0.3	0	0

Input D:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-2.3.2.4.6.2D: Input D: Preamble Pulse Characteristics

Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	—
2	0.05 - 0.1	0.05 - 0.2	0	-0.125	0
3	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	0
4	0.05 - 0.1	0.05 - 0.2	0	+0.125	0

Input E:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-2.3.2.4.6.2E: Input E: Preamble Pulse Characteristics

Pulse	**Rise time** (µsec)	**Fall time** (µsec)	**Δ Width** (µsec)	**Δ Position** (µsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	—
2	0.05 - 0.1	0.05 - 0.2	0	+0.125	0
3	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	0
4	0.05 - 0.1	0.05 - 0.2	0	-0.125	0

Input F:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-2.3.2.4.6.2F: Input F: Preamble Pulse Characteristics

Pulse	**Rise time** (µsec)	**Fall time** (µsec)	**Δ Width** (µsec)	**Δ Position** (µsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+4.5	—	—
2	Pulse Not Present				
3	Pulse Not Present				
4	Pulse Not Present				

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level is adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures is lowered by 3 dB.

Step 1: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 2: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 2

Repeat Step 1 with the signal power level at -65 dBm.

Step 3: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 3

Apply **Input B** at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 4: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 4

Repeat Step 3 with the signal power level at -65 dBm.

Step 5: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 1

Apply **Input C** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 6: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 2

Repeat Step 5 with the signal power level at -65 dBm.

Step 7: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 1

Apply **Input D** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 8: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 2

Repeat Step 7 with the signal power level at -65 dBm.

Step 9: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 3

Apply **Input E** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 10: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 4

Repeat Step 9 with the signal power level at -65 dBm.

Step 11: Preamble Single Pulse - Part 1

Apply **Input F** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 12: Preamble Single Pulse - Part 2

Repeat Step 11 with the signal power level at -65 dBm.

2.3.2.4.7 Criteria for Data Block Acceptance in ADS-B Message Signals (§2.2.4.3.4.7.3)

Purpose/Introduction:

This test procedure verifies that ADS-B Messages are accepted when DF field is 17 or 18 and when no more than seven consecutive bits fail the confidence test, as specified by §2.2.4.3.4.7.3.

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-50 dBm

The normal data block content **shall** be modified to contain energy throughout both halves (i.e., chips) of bit positions 33 to 39. The amplitude of the pulse in the half that would ordinarily contain no energy **shall** be 2 dB below the amplitude of the normal pulse in the other half of the bit position. The data values in bit positions 33 to 39 **shall** be chosen so that at least one of these bits will be detected by the UUT with the incorrect bit value.

Input B:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	18
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-50 dBm

The normal data block content **shall** be modified to contain energy throughout both halves (i.e., chips) of bit positions 33 to 39. The amplitude of the pulse in the half that would ordinarily contain no energy **shall** be 2 dB below the amplitude of the normal pulse in the other half of the bit position. The data values in bit positions 33 to 39 **shall** be chosen so that at least one of these bits will be detected by the UUT with the incorrect bit value.

Input C:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz.
Frequency	=	1090 MHz
Power	=	-50 dBm

The normal data block content **shall** be modified to contain energy throughout both halves (i.e., chips) of bit positions 33 to 40. The amplitude of the pulse in the half that would ordinarily contain no energy **shall** be 2 dB below the amplitude of the normal pulse in the other half of the bit position. The data values in bit positions 33 to 40 **shall** be chosen so that at least one of these bits will be detected by the UUT with the incorrect bit value.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Valid DF=17 ADS-B Message

Apply **Input A** at the receiver input and verify that all ADS-B Messages are correctly decoded.

Step 2: Valid DF=18 ADS-B Message

Apply **Input B** at the receiver input and verify that all ADS-B Messages are correctly decoded.

Step 3: Corrupted DF=17 ADS-B Messages - Part 1

Apply **Input C** at the receiver input and verify that ADS-B Messages are not decoded.

Step 4: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.3.2.4.8 Verification of Enhanced Squitter Reception Techniques (§2.2.4.4)

No specific test procedures are required to validate §2.2.4.4.

2.3.2.4.8.1 Combined Preamble and Data Block Tests with A/C Fruit (§2.4.4.4.2.4)

Purpose/Introduction:

The following tests verify the performance of the equipment under test in decoding the Extended Squitter preamble and data block overlapped with Mode A/C FRUIT while being subjected to environmental conditions.

Equipment:

Refer to §2.4.4.4.2.1.1 for Mode A/C Fruit Signal Source test requirements.

Refer to §2.4.4.4.2.1.3 for Extended Squitter Signal Source test requirements.

Measurement Procedure:

Step 1: Verification of Operation of Equipment Under Test

Connect the Extended Squitter signal source and set the power level at the receiver input equal to the MTL limit required for the UUT equipment class:

–79 dBm for A1S and A1 equipment class or,

–79 dBm for A2 equipment class or,

–84 dBm for A3 equipment class.

Inject the Extended Squitter signal **100** times and record the Extended Squitters that are declared to be output as error free. Compare the decoded content of each Extended Squitter with the known content of the injected Extended Squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 90% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2: Test with Three Mode A/C Fruit Overlaps

Set the Extended Squitter signal source as specified in Step 1.

Set the power level of three Mode A/C FRUIT sources at the receiver input to the value corresponding to the UUT equipment class:

-71, -67 and –63 dBm for A1S, A1 or A2 equipment class or,

-76, -72 and –68 dBm for A3 equipment class.

Activate the Mode A/C FRUIT source so that the FRUIT is pseudo randomly distributed across the Extended Squitter preamble and data block as specified in §2.4.4.4.2.1.

Inject the Extended Squitter waveform **100** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Step 3: Determination of Success or Failure

Compare the results recorded above with the appropriate requirements in Table 2-114, Table 2-115 or Table 2-116.

Table 2-114: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A1S and A1 Equipment

Number of Fruit	**3**
Minimum Probability	0.53
Max Undetected Errors	1

Table 2-115: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A2 Equipment

Number of Fruit	**3**
Minimum Probability	0.88
Max Undetected Errors	1

Table 2-116: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A3 Equipment

Number of Fruit	**3**
Minimum Probability	0.90
Max Undetected Errors	1

2.3.2.4.8.2 Data Block Tests with Mode S Fruit (§2.4.4.4.2.5)

Purpose/Introduction:

The following tests verify the performance of the equipment under test in decoding the Extended Squitter data content overlapped with Mode S FRUIT while being subjected to environmental conditions.

Equipment:

Refer to §2.4.4.4.2.1.2 for Mode S Fruit Signal Source test requirements.

Refer to §2.4.4.4.2.1.3 for Extended Squitter Signal Source test requirements.

Measurement Procedure:

Step 1: Verification of Operation of Equipment Under Test

Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Inject the signal **100** times and record the Extended Squitters that are declared to be output as error free. Compare the decoded content of each Extended Squitter with the known content of the injected Extended Squitter.

Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 95% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2: Test with One Mode S Fruit Overlap

Set the Extended Squitter signal source as specified in Step 1.

Activate the Mode S FRUIT source so that the Mode S FRUIT is pseudo randomly distributed across the data Extended Squitter data block as specified in §2.4.4.4.2.1.2.

Set the Extended Squitter power to 0 dB relative to the Mode S FRUIT signal level.

Inject the Extended Squitter waveform **100** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of signal to interference (S/I) of +8 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the four power levels.

Step 3: Determination of Success or Failure

Compare the results recorded above with the appropriate requirements in Table 2-117, Table 2-118 or Table 2-119.

Table 2-117: Success Criteria for Data Block Tests with Mode S Fruit – Class A1S and A1 Equipment

Relative Power (S/I) dB	**0**	**+8**
Minimum Probability	0	0.99
Max Undetected Errors	1	1

Table 2-118: Success Criteria for Data Block Tests with Mode S Fruit – Class A2 Equipment

Relative Power (S/I) dB	0	+8
Minimum Probability	0	0.99
Max Undetected Errors	1	1

Table 2-119: Success Criteria for Data Block Tests with Mode S Fruit – Class A3 Equipment

Relative Power (S/I) dB	0	+8
Minimum Probability	0	0.99
Max Undetected Errors	1	1

2.3.2.4.8.3 Re-Triggering Performance (§2.4.4.4.2.6)

Purpose/Introduction:

The following tests verify the performance of the equipment under test to detect Extended Squitters that are preceded by lower level Mode S FRUIT while being subjected to environmental conditions.

Equipment:

Refer to §2.4.4.4.2.1.2 for Mode S Fruit Signal Source test requirements.

Refer to §2.4.4.4.2.1.3 for Extended Squitter Signal Source test requirements.

Measurement Procedure:

Step 1: Verification of Operation of Equipment Under Test

Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Inject the signal **100** times and record the Extended Squitters that are declared to be output as error free. Compare the decoded content of each Extended Squitter with the known content of the injected Extended Squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 95% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2: Re-triggering Test with Varying Position Mode S Fruit

Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Set the Extended Squitter power to +4 dB relative to the Mode S FRUIT signal level.

Activate the Mode S FRUIT source so that the 112-bit Mode S FRUIT signal is uniformly randomly distributed across the time interval beginning at –112 microseconds and ending at –6 microseconds relative to the signal. The time indicated is the spacing between the P1 pulse of the signal and the P1 pulse of the FRUIT, where negative values indicate that the FRUIT is received earlier.

Inject the Extended Squitter waveform **T** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of Signal to Interference (S/I) of +12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the three power levels.

Compare the results recorded above with the appropriate requirements in Table 2-120, Table 2-121 or Table 2-122.

Table 2-120: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A1S and A1 Equipment

Relative Power, (S/I) dB	**+4**	**+12**
Minimum Probability	0.12	0.91
Max Undetected Errors	1	1

Table 2-121: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A2 Equipment

Relative Power, (S/I) dB	**+4**	**+12**
Minimum Probability	0.12	0.94
Max Undetected Errors	1	1

Table 2-122: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A3 Equipment

Relative Power, (S/I) dB	**+4**	**+12**
Minimum Probability	0.12	0.94
Max Undetected Errors	1	1

2.3.2.4.9 Track File Maintenance (§2.2.8 through §2.2.10)

Purpose/Introduction:

This procedure is used to verify the general performance characteristics of the ADS-B Receiving Subsystem under environmental conditions. The scenarios described herein should be repeated as needed to test the various aspects of the environmental requirements of the ADS-B Receiving Subsystem.

Equipment:

Provide a method of loading valid ADS-B Broadcast messages of all types into the ADS-B Receiving Subsystem under test. Provide a method of loading valid position information into the ADS-B Receiving Subsystem under test.

Measurement Procedure:

Step 1: Establish ADS-B Receiving Subsystem Position

Provide the ADS-B Receiving Subsystem with valid position data as listed in Table 2-123.

Step 2: Surface Participant Stimulus and Track File Maintenance

At a reference time of time zero, begin generation of a series of "even" and "odd" Surface Position from Participants 1 through 4 shown in Table 2-123. Each Message should be structured using subfield data shown in Table 2-123. Each message should be provided at the appropriate rate in accordance with §2.2.3.3.2.2.

a. For Receiving Functions that provide only Output Messages in accordance with §2.2.6, verify that the Receiving function delivers appropriate Output Messages to the user interface or to the Report Assembly function for all Surface Participants.

b. For Receiving Functions that provide a Report Assembly function, verify that the Receiving function delivers appropriate State Vector Reports for all Surface Participants in accordance with §2.2.8.1.

Step 3: Airborne Participant Stimulus and Track File Maintenance

While continuing to transmit the Surface Position Messages described in Step 1, begin generation of a series of "even" and "odd" Airborne Position Messages from Participants 5 through 28 shown in Table 2-123. Each message should be structured using subfield data shown in Table 2-123. Each message should be provided at the appropriate rate in accordance with §2.2.3.3.2.2.

While continuing to transmit the messages required by Step 1 and the previous paragraph, begin generation of Airborne Velocity Messages for participants 5 through 28. Each message should be structured using subfield data shown in Table 2-123. Each message should be provided at the appropriate rate in accordance with §2.2.3.3.2.5.

a. For Receiving Functions that provide only Output Messages in accordance with §2.2.6, verify that the Receiving function delivers appropriate Output Messages to the user interface or to the Report Assembly function for all Airborne Participants.

b. For Receiving Functions that provide a Report Assembly function, verify that the Receiving function delivers appropriate State Vector Reports for all Airborne Participants in accordance with §2.2.8.1.

Step 4: Broadcast Message Termination

Terminate the delivery of broadcast messages for all participants. Wait for at least 200 seconds.

a. For Receiving Functions that provide only Output Messages in accordance with §2.2.6, verify that the Receiving function ceases to deliver Output Messages to the user interface or to the Report Assembly function for All Participants.

b. For Receiving Functions that provide a Report Assembly function, verify that the Receiving function ceases to deliver State Vector Reports for all Airborne Participants.

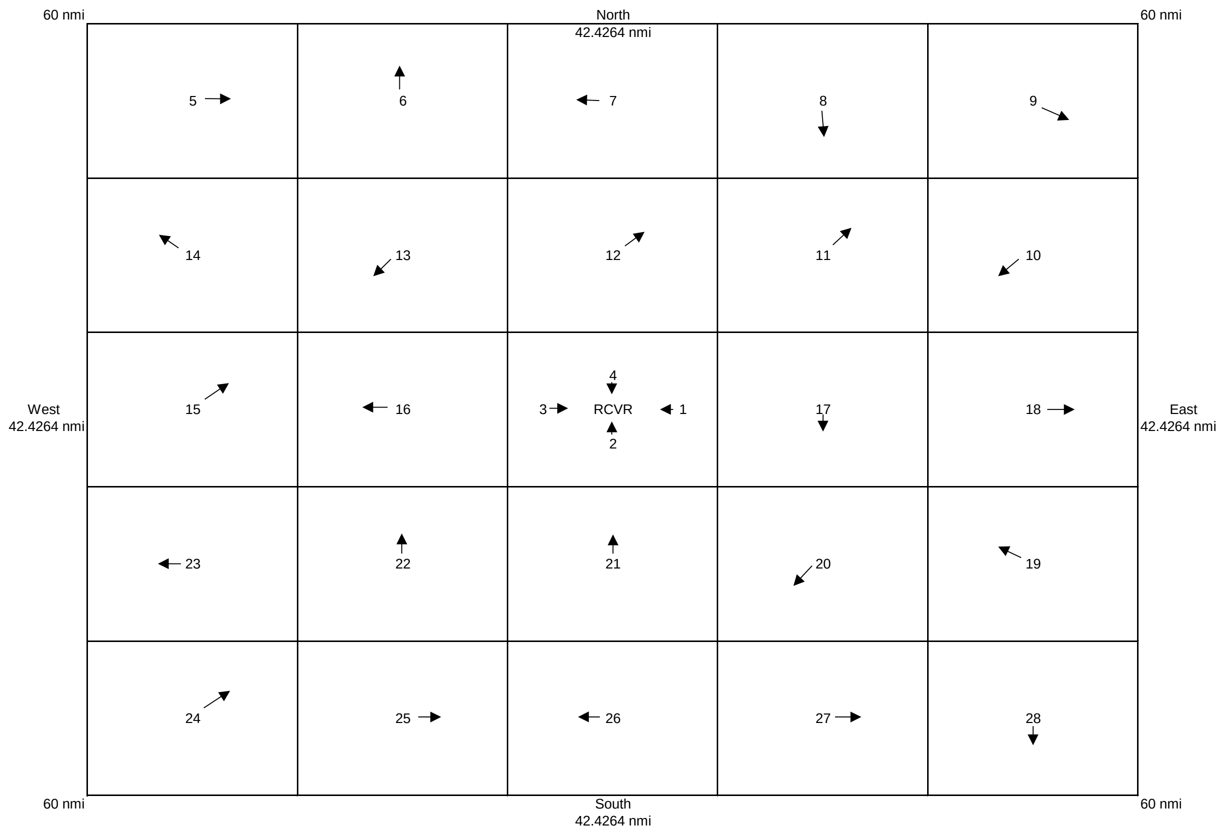


Figure 2-32: ADS-B Receiving Subsystem Environmental Test Scenario Pattern

Note: *Figure 2-32 provides a visual indication of the placement of the participants listed in Table 2-123.*

Table 2-123: ADS-B Receiving Subsystem Environmental Test Scenario

Target Number	DF (Binary)	CA (Binary)	AA (HEX)	Latitude	Longitude	Altitude (feet)	E/W Direction Bit (Binary)	E/W Velocity (knots)	N/S Direction Bit (Binary)	N/S Velocity (knots)	Ground Speed (knots)	Ground Track (degrees)
UUT Receiver Location				33.9425361	-118.4080744	126						
1	1 0001	100	AA AA AA	33.9425361	-118.3833333	126					10	270
2	1 0001	100	AA BB BB	33.9166666	-118.4080744	126					25	357
3	1 0001	100	AA CC CC	33.9425361	-118.4250000	126					35	90
4	1 0001	100	AA DD DD	33.9583333	-118.4080744	126					60	180
5	1 0001	101	BB AA AA	34.6496427	-119.1151811	35000	0	600	0	0		
6	1 0001	101	BB BB BB	34.6496427	-118.7616277	20000	0	0	0	700		
7	1 0001	101	BB CC CC	34.6496427	-118.4080744	10000	1	500	0	0		
8	1 0001	101	BB DD DD	34.6496427	-118.0545211	15000	0	0	1	550		
9	1 0001	101	BB EE EE	34.6496427	-117.7009677	9000	0	500	1	500		
10	1 0001	101	CC AA AA	34.2960894	-117.7009667	25000	1	400	1	400		
11	1 0001	101	CC BB BB	34.2960894	-118.0545211	15000	0	300	0	300		
12	1 0001	101	CC CC CC	34.2960894	-118.4080744	12000	0	250	0	250		
13	1 0001	101	CC DD DD	34.2960894	-118.7616277	30000	1	400	1	400		
14	1 0001	101	CC EE EE	34.2960894	-119.1151811	37000	1	600	0	600		
15	1 0001	101	DD AA AA	33.9425361	-119.1151811	8000	0	300	0	300		
16	1 0001	101	DD BB BB	33.9425361	-118.7616277	29000	1	600	0	0		
17	1 0001	101	DD CC CC	33.9425361	-118.0545211	26000	0	0	1	650		
18	1 0001	101	DD DD DD	33.9425361	-117.7009667	28000	0	600	0	0		
19	1 0001	101	DD EE EE	33.5889827	-117.7009667	31000	1	600	0	600		
20	1 0001	101	EE AA AA	33.5889827	-118.0545211	25000	1	400	1	400		
21	1 0001	101	EE BB BB	33.5889827	-118.4080744	14000	0	0	0	300		
22	1 0001	101	EE CC CC	33.5889827	-118.7616277	15000	0	0	0	300		
23	1 0001	101	EE DD DD	33.5889827	-119.1151811	16000	1	900	0	0		
24	1 0001	101	EE EE EE	33.2354294	-119.1151811	15000	0	400	0	500		
25	1 0001	101	FF AA AA	33.2354294	-118.7616277	36000	0	700	0	0		
26	1 0001	101	FF BB BB	33.2354294	-118.4080744	19000	1	600	0	0		
27	1 0001	101	FF CC CC	33.2354294	-118.0545211	25000	0	955	0	0		
28	1 0001	101	FF DD DD	33.2354294	-117.7009667	35000	0	0	1	850		

2.3.2.5 Self Test and Monitors (§2.2.11)

No specific test procedure is required to validate §2.2.11.

2.3.2.5.1 Transponder-Based Equipment Address (§2.2.11.3.1)

Transponder-Based Equipment **shall** be tested in accordance with the procedures provided in §2.3.2.5.2.

Note: *The requirement to test Transponder-Based equipment is provided herein due to the fact that the test requirements provided in RTCA DO-181D do not test the function adequately.*

2.3.2.5.2 Non-Transponder-Based Equipment (§2.2.11.3.2)

Purpose/Introduction:

The following Test Procedures **shall** be used to verify that the ADS-B Transmitting monitor function properly enunciates the "Fail Warn" condition in the event that the ICAO 24-Bit Address (§2.2.5.1.1) provided to the ADS-B Transmitting Subsystem is set to ALL ZEROs or ALL ONEs.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting and monitoring ADS-B broadcast messages. Provide a method of modifying the ICAO 24-Bit Address provided to the Unit Under Test.

Measurement Procedure:

Step 1: Initial Conditions

Establish any state where the ADS-B Transmission Function is operational and indicating no Fail Warn conditions.

Step 2: Address set to ALL ZEROs

Remove power from the Unit Under Test (UUT). Set the ICAO 24-Bit Address provided to the UUT to ALL ZEROs. Apply power to the UUT. Verify that the ADS-B transmission function properly enunciates the "Fail Warn" state within no more than 2.0 seconds.

Step 3: New Initial Conditions

Repeat Step 1.

Step 4: Address set to ALL ONEs

Remove power from the Unit Under Test (UUT). Set the ICAO 24-Bit Address provided to the UUT to ALL ONEs. Apply power to the UUT. Verify that the

ADS-B transmission function properly enunciates the "Fail Warn" state within no more than 2.0 seconds.

Step 5: Restore Normal Operations

Establish any state where the ADS-B Transmission Function is operational and indicating no Fail Warn conditions prior to continuing with further testing.

2.3.2.6 Response to Mutual Suppression Pulses (§2.2.12)

No specific test procedure is required to validate §2.2.12.

2.3.2.6.1 Transmitting Device Response to Mutual Suppression Pulses (§2.2.12.1)

Purpose/Introduction:

The following Test Procedures **shall** be used to verify that the ADS-B Transmitting Subsystem functions properly in the Mutual Suppression environment.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of supplying the ADS-B Transmitting Subsystem with Mutual Suppression Pulses. Provide a method of monitoring and recording ADS-B transmissions and the time at which such transmissions are generated with respect to the end of a mutual suppression pulse.

Measurement Procedure:

Step 1: Initialize ADS-B Airborne Participant Transmissions

Provide the ADS-B Transmitting Subsystem with all necessary information to enable the transmitting function to generate the following DF=17 transmitted messages:

(1). Airborne Position Messages (§2.2.3.2.3),

(2). Aircraft Identification and Category Messages (§2.2.3.2.5), and

(3). Airborne Velocity Messages (§2.2.3.2.6)

Verify that the ADS-B Transmitting Subsystem properly transmits Airborne Position, Aircraft Identification and Category, and Airborne Velocity Messages at the rates required in §2.2.3.3.2.2, §2.2.3.3.2.4 and §2.2.3.3.2.5.

Step 2: Apply Mutual Suppression

Apply Mutual Suppression pulses of the maximum length that the suppression interface is designed to accept. Verify that no ADS-B transmissions occur during the suppression period.

Record the transmissions that are generated and verify that transmissions can be output no later than 15 microseconds after the end of the mutual suppression pulse.

2.3.2.6.2 Receiving Device Response to Mutual Suppression Pulses (§2.2.12.2)

Purpose/Introduction:

The following Test Procedures **shall** be used to verify that the ADS-B Receiving device functions properly in the Mutual Suppression environment.

Equipment Required:

Provide a method of supplying ADS-B Transmitted messages to the ADS-B Receiving Subsystem. Provide a method of supplying the ADS-B Receiving Subsystem with Mutual Suppression Pulses that can be synchronized to the ADS-B Transmitted messages provided to the ADS-B Receiving Subsystem. Provide a method of monitoring and recording the Receiving function decoded ADS-B Messages or structured ADS-B Reports.

Measurement Procedure:

Step 1: Initialize ADS-B Message Reception

Provide the ADS-B Receiving Subsystem with appropriate ADS-B Messages at a minimum rate of two per second and having a signal level of the Receiver MTL + 3 dB. Verify that the Receiving function decodes at least 99 % of the messages provided to the receiver.

Step 2: Apply Mutual Suppression

a. Apply Mutual Suppression pulses synchronized to start before each ADS-B Message provided to the Receiving function.

   Ensure that the duration of each Mutual Suppression pulse exceeds that of the ADS-B Messages being provided to the Receiving function. Verify that no ADS-B Messages are successfully decoded by the Receiving function.

b. Apply Mutual Suppression pulses that do not over lap any of the ADS-B Messages provided to the Receiving function and are synchronized to finish 15 microseconds prior to the start of each ADS-B Message provided to the Receiving function. Verify that at least 90 percent of the ADS-B Messages provided to the Receiving function are properly decoded by the Receiving function.

2.3.2.7 Diversity Operation (§2.2.13.6)

No specific test procedure is required to validate §2.2.13.6.

2.3.2.7.1 Transmitting Diversity (§2.2.13.6.1)

Purpose/Introduction:

This test procedure verifies that an ADS-B Transmitting Subsystem implements transmitting diversity properly by transmitting each required type of ADS-B Message alternately from the top and bottom antennas.

Equipment Required:

Provide a method of supplying the ADS-B Transmitting Subsystem with all data necessary to structure ADS-B Airborne Position, Airborne Velocity, and Aircraft Identification and Category messages. All data **shall** be provided via the operational interfaces. Provide a method of monitoring the ADS-B Broadcast Messages transmitted by the ADS-B Transmitting Subsystem.

Measurement Procedure:

Step 1: Broadcast Message Initialization

Provide the ADS-B Transmitting Subsystem with all data necessary to structure Airborne Position, Airborne Velocity, and Aircraft Identification and Category ADS-B Broadcast Messages.

Step 2: Broadcast Message Verification

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Airborne Position Messages alternately on the Top and Bottom RF ports.

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Airborne Velocity Messages alternately on the Top and Bottom RF ports.

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Aircraft Identification and Category Messages alternately on the Top and Bottom RF ports.

2.3.2.7.2 Receiving Diversity (§2.2.13.6.2)

Appropriate test procedures to required to verify the performance of §2.2.13.6.2 are provided in §2.3.2.7.2.1 through §2.3.2.7.2.2.

2.3.2.7.2.1 Full Receiver and Message Processing or Receiver Switching Front-End Diversity (§2.2.13.6.2)

Purpose/Introduction:

This procedure verifies that the ADS-B Receiving Subsystem properly implements diversity by demonstrating proper reception of ADS-B Broadcast Messages from either the top antenna, or the bottom antenna, or both antennas. This procedure applies to those configurations that implement Full receiver and message processing function diversity as discussed in §2.2.13.6.2.a. This procedure also apples to those configurations that implement Receiver Switching Front-End diversity as discussed in §2.2.13.6.2.b.

Equipment Required:

Provide a method of supplying the equipment under test with appropriate Airborne Position ADS-B Broadcast Messages. Provide a method of monitoring the Output Messages and/or ADS-B Reports generated by the ADS-B Receiving Subsystem. Provide an RF Splitter/Combiner (2 port, or 3 dB type). Provide RF Attenuators (Fixed, various attenuation values, as needed)

Measurement Procedure:

Step 1: Test Equipment Configuration

Connect the ADS-B Broadcast Message generator to the RF Splitter input. Connect each output from the RF Splitter to the input of an RF Attenuator. Connect the output of one RF Attenuator to the Top Channel RF input port of the equipment under test. Connect the output of the other RF Attenuator to the Bottom Channel RF input port of the equipment under test.

Step 2: Top Channel is Primary Receiver

Adjust the Top Channel attenuator such that the signal level provided to the Top Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Adjust the Bottom Channel attenuator such that the signal level provided to the Bottom Channel RF input port is 20 dB less than the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 90% of the Airborne Position Messages provided to the Top Channel RF input port.

Step 3: Bottom Channel is Primary Receiver

Adjust the Bottom Channel attenuator such that the signal level provided to the Bottom Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Adjust the Top Channel attenuator such that the signal level provided to the Top Channel RF input port is 20 dB less than the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 90% of the Airborne Position Messages provided to the Bottom Channel RF input port.

Step 4: Top / Bottom Channel Equivalent

Adjust the Bottom Channel attenuator such that the signal level provided to the Bottom Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Adjust the Top Channel attenuator such that the signal level provided to the Top Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for between 90% and 100% of the Airborne Position Messages provided to the Bottom Channel RF input port.

2.3.2.7.2.2 Receiving Antenna Switching Diversity (§2.2.13.6.2)

Purpose/Introduction:

This procedure verifies that the ADS-B Receiving Subsystem properly implements diversity by demonstrating proper reception of ADS-B Broadcast Messages from either the top antenna or the bottom antenna. This procedure applies to those configurations that implement Receiving Antenna switching as discussed in §2.2.13.6.2.c.

Equipment Required:

Provide a method of supplying the equipment under test with appropriate Airborne Position ADS-B Broadcast Messages. Provide a method of monitoring the Output Messages and/or ADS-B Reports generated by the ADS-B Receiving Subsystem. Provide RF Attenuators (Fixed, various attenuation values, as needed).

Measurement Procedure:

Step 1: Top Channel is Primary Receiver

Connect the ADS-B Broadcast Message generator to the RF Attenuator input. Connect the output of the RF Attenuator to the Top Channel RF input port of the equipment under test.

Adjust the attenuator such that the signal level provided to the Top Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 45% of the Airborne Position Messages provided to the Top Channel RF input port.

Step 2: Bottom Channel is Primary Receiver

Connect the ADS-B Broadcast Message generator to the RF Attenuator input. Connect the output of the RF Attenuator to the Bottom Channel RF input port of the equipment under test.

Adjust the attenuator such that the signal level provided to the Bottom Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 45% of the Airborne Position Messages provided to the Bottom Channel RF input port.

2.3.2.8 Power Interruption (§2.2.15)

Appropriate test procedures are found in §2.3.2.8.1 and §2.3.2.8.2.

2.3.2.8.1 Power Interruption to ADS-B Transmitting Subsystems (§2.2.15)

Purpose/Introduction:

The purpose of this procedure is to verify that the ADS-B Transmitting Subsystem regains operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

Equipment Required:

Provide equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B Transmitting Subsystem under test through the operational interface.

Measurement Procedure:

Step 1: Enable Transmission of Airborne Position Messages

Supply the ADS-B Transmitting Subsystem with the appropriate data necessary to establish Airborne Position Messages.

Verify that the ADS-B Transmitting Subsystem generates appropriate Airborne Position Messages at the rate specified in §2.2.3.3.1.1 or §2.2.3.3.2.2.

Note: *If the Transmission function uses diversity and the test is being performed on one RF output interface at a time, then the specified rate necessary to satisfy this test is half of that given in §2.2.3.3.1.1 or §2.2.3.3.2.2.*

Step 2: Apply momentary power interrupts

Apply momentary power interrupts to the ADS-B Transmitting Subsystem under test in accordance with RTCA DO-160F section 16 and (EUROCAE ED-14F, section 16). Then restore the power to normal operating conditions.

Verify that the ADS-B Transmitting Subsystem resumes generation of appropriate Airborne Position Messages no later than 2.0 seconds after the restoration of normal power.

Step 3: Repeat for additional RF Output Interfaces

If the ADS-B Transmitting Subsystem implements diversity, then repeat steps 1 and 2 on the additional RF Output Interface.

2.3.2.8.2 Power Interruption to ADS-B Receiving Subsystems (§2.2.15)

Purpose/Introduction:

The purpose of this procedure is to verify that the ADS-B Receiving Subsystem regains operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

Equipment Required:

Provide equipment capable of supplying valid ADS-B broadcast messages to the ADS-B Receiving Subsystem under test via the appropriate RF interface.

Measurement Procedure:

Step 1: Enable Reception of Airborne Position Messages

Via the receiver RF interface and in the absence of interference, apply valid 1090 MHz. Airborne Position Messages at a uniform rate of 2 per second and at a signal level that is at least 15 dB above the MTL of the ADS-B Receiving Subsystem.

Verify that the ADS-B Receiving Subsystem delivers appropriate Output Messages to the user interface or to the Report Assembly function for all messages received and that the Output Message formats are consistent with the requirements of §2.2.6.1.1.

Step 2: Apply momentary power interrupts

Apply momentary power interrupts to the ADS-B Receiving Subsystem under test in accordance with RTCA DO-160F section 16 (EUROCAE ED-14F, section 16). Then restore the power to normal operating conditions.

Verify that the ADS-B Receiving Subsystem resumes generation of appropriate Output Messages to the user interface or to the Report Assembly function no later than 2.0 seconds after the restoration of power.

Then verify that the ADS-B Receiving Subsystem continues to deliver appropriate Output Messages to the user interface or to the Report Assembly function for all messages received and that the Output Message formats are consistent with the requirements of §2.2.6.1.1.

Step 3: Repeat for additional RF Output Interfaces

If the ADS-B Receiving Subsystem implements diversity, then repeat steps 1 and 2 on the additional RF Input Interface.

2.3.2.9 Verification of Traffic Information Services – Broadcast (TIS-B) (§2.2.17)

No specific test procedure is required to validate the requirements of §2.2.17.

2.3.2.9.1 Verfication of TIS-B Report Generation (§2.2.17.4.6)

Measurement Procedure:

Step 1: Verification of Non-Position Report Elements and Timing

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B message.

Verify that within 0.5 seconds of the receipt of this message that all of the non-position elements are reported directly as received. Repeat this step for each of the TIS-B message types.

Step 2: Verification of Position Report Elements and Timing

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B message.

Verify that within 0.5 seconds of the receipt of this message that all of the position elements (latitude, longitude, altitude, address and TOA) are reported directly as well as all of the other information received. Repeat this step for each of the TIS-B message types.

2.4 Equipment Test Procedures

The test procedures set forth in the following subparagraphs are considered satisfactory for use in determining required performance under standard and stressed conditions. Although specific test procedures are cited, it is recognized that other methods may be preferred by the testing facility. These alternate procedures may be used if the equipment manufacturer can show that they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

2.4.1 Definition of Terms and Conditions of Test

The following definitions of terms and conditions of tests are applicable to the equipment tests specified herein commencing at §2.4.2:

a. Power Input Voltage - Unless otherwise specified, all tests **shall** be conducted with the power input voltage adjusted to design voltage ±2 percent. The input voltage **shall** be measured at the input terminals of the equipment under test.

b. Power Input Frequency

   (1). In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency **shall** be adjusted to design frequency ±2 percent.

   (2). If the equipment is designed for operation from an AC source of variable frequency (e.g., 300 to 1000 Hz), tests **shall** be conducted with the input frequency adjusted to within five percent of a selected frequency and, unless otherwise specified, within the range for which the equipment is designed.

c. Accuracy of Test Equipment - Throughout this section, the accuracy of the test equipment is not addressed in detail, but rather is left to the calibration process prescribed by the agency which certifies the testing facility.

d. Adjustment of Equipment - The circuits of the equipment under test **shall** be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests. Unless otherwise specified, adjustments may not be made once the test procedures have started.

e. Test Instrument Precautions - During the tests, precautions **shall** be taken to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments, across the input and output terminals of the equipment under test.

f. Ambient Conditions - Unless otherwise specified, all tests **shall** be conducted under conditions of ambient room temperature, pressure and humidity. However, the room temperature **shall** not be lower than 10 degrees C.

g. Connected Loads - Unless otherwise specified, all tests **shall** be performed with the equipment connected to loads having the impedance values for which it is designed.

h. Standard ADS-B Broadcast Message Test Signals

The ADS-B Broadcast Message general signal conventions **shall** be as specified in §2.2.2 and §2.2.3 through §2.2.3.2.1.7.

General Characteristics

(a). Radio Frequency: - The carrier frequency of the signal generator for ADS-B Broadcast Messages **shall** be 1090 ±1.0 MHz.

(b). CW Output: - The CW output between pulses **shall** be at least 50 dB below the peak level of the pulse.

(c). Pulse Rise and Fall Time: - Rise and fall times **shall** be as specified in §2.2.3.1.3.

(d). Pulse Top Ripple: - The instantaneous amplitude of the pulses **shall** not fall more than 1 dB below the maximum value between the 90 percent voltage amplitude points on the leading and trailing edge of a pulse.

(e). Signal Level: - Unless otherwise noted in the measurement procedure, the signal level **shall** be -60 ±3 dBm.

(f). Broadcast Message Rate: - Unless otherwise noted in the measurement procedure, ADS-B Broadcast Message Rates **shall** be 60 ±5 Hz.

(g). ICAO 24-Bit Discrete Address: - Unless otherwise noted in the measurement procedure, the ADS-B Transmitting Subsystem address used for all broadcast messages **shall** be: Hexadecimal – AA AAAA, (i.e., binary – 1010 1010 1010 1010 1010 1010).

2.4.2 Verification of ADS-B Transmitter Characteristics (§2.2.2)

No specific test procedure is required to validate §2.2.2.

2.4.2.1 Mode S Transponder-Based Transmitters (§2.2.2.1)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2 (EUROCAE ED-73C, section 3.3) inclusive.

Note: *Class A0 and Class B0 equipment is limited to aircraft equipment only permitted to operate below 15,000 feet.*

2.4.2.1.1 Verification of RF Peak Output Power (minimum) (§2.2.2.1.1)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

2.4.2.1.1.1 Verification of Class A0 ADS-B Transponder-Based Transmitter Power (§2.2.2.1.1.1)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

In addition, the equipment **shall** be tested in accordance with §2.4.2.2.10.1 of this document.

2.4.2.1.1.2 Verification of Class A1S and A1 ADS-B Transponder-Based Transmitter Power (§2.2.2.1.1.2)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

2.4.2.1.1.3 Verification of Class A2 ADS-B Transponder-Based Transmitter Power (§2.2.2.1.1.3)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

2.4.2.1.1.4 Verification of Class A3 ADS-B Transponder-Based Transmitter Power (§2.2.2.1.1.4)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

2.4.2.1.1.5 Verification of Class B ADS-B Transponder-Based Transmitter Power (§2.2.2.1.1.5)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

When the RF Peak Output Power (minimum) tests are not specified by RTCA DO-181D (EUROCAE ED-73C), then the equipment **shall** be tested in accordance with §2.4.2.2.10.2 of this document.

2.4.2.1.2 Verification of RF Peak Output Power (maximum) (§2.2.2.1.2)

Transponder-based transmitters **shall** be tested to comply with the requirements of RTCA DO-181D, §2.4.2.2.2 (EUROCAE ED-73C, §3.3.3).

When the RF Peak Output Power (maximum) tests are not specified by RTCA DO-181D (EUROCAE ED-73C), then the equipment **shall** be tested in accordance with §2.4.2.2.10.3 of this document.

2.4.2.2 Verification of Stand Alone Transmitters (§2.2.2.2)

No specific test procedure is required to validate §2.2.2.2.

2.4.2.2.1 Verification of Transmission Frequency (§2.2.2.2.1)

Equipment Required:

Provide equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test through the operational interface. Provide a Stub Tuner (Microlab/FXR Sl-05N, or equivalent). Provide a Variable Air Line (Line Stretcher) (Microlab/FKR SR-05N, or equivalent). Provide a Slotted Line (HP 805C, or equivalent).

Measurement Procedure:

Determine the transmission frequency

Load valid Airborne Position Data into the ADS-B Transmitting Subsystem and ensure that the expected ADS-B transmissions occur. Adjust the stub to establish a l.5:l VSWR at the antenna end of the coax line specified by the manufacturer. If the ADS-B Transmitting Subsystem requires a minimum length of a specified cable type, an attenuator equal to the loss of the minimum amount of cable may be placed between the 1.5:1 VSWR point and the equipment antenna jack. Alternately, a length of cable equal to the specified minimum length and cable type may be used in lieu of the attenuator. Adjust the line stretcher for maximum transmitter frequency shift above and below 1090 MHz. Determine that the frequency shift does not exceed the requirements of §2.2.2.2.1.

2.4.2.2.2 Verification of Transmission Spectrum (§2.2.2.2.2)

Test procedures to validate the spectrum requirements for the ADS-B transmitted message are provided in §2.4.3.1.3 of this document.

2.4.2.2.3 Verification of Modulation (§2.2.2.2.3)

Test procedures to validate the modulation requirements for the ADS-B transmitted message are provided in §2.4.3.1.1 and §2.4.3.1.2 of this document.

2.4.2.2.4 Verification of Pulse Shapes (§2.2.2.2.4)

Test procedures to validate the pulse shape requirements for the ADS-B transmitted message are provided in §2.4.3.1.3 of this document.

2.4.2.2.5 Verification of Message Structure (§2.2.2.2.5)

Test procedures to validate the message structure requirements for the ADS-B transmitted message are provided in §2.4.3.1.1 through §2.4.3.1.4 of this document.

2.4.2.2.6 Verification of Pulse Intervals (§2.2.2.2.6)

Test procedures to validate the pulse interval requirements for the ADS-B transmitted message are provided in §2.4.3.1.4 of this document.

2.4.2.2.7 Verification of Preamble (§2.2.2.2.7)

Appropriate test procedures to validate the ADS-B Message Preamble are provided in §2.4.3.1.1 of this document.

2.4.2.2.8 Verification of Data Pulses (§2.2.2.2.8)

Appropriate test procedures to validate the ADS-B Message Data pulses are provided in §2.4.3.1.2 of this document.

2.4.2.2.9 Verification of Pulse Amplitude (§2.2.2.2.9)

Appropriate test procedures to validate the ADS-B Message Data Pulse amplitudes are provided in §2.4.3.1.3 of this document.

2.4.2.2.10 Verification of RF Peak Output Power (§2.2.2.2.10)

No specific test procedure is required to validate §2.2.2.2.10, which provides only general information.

2.4.2.2.10.1 Verification of Class A0 Equipment RF Peak Output Power (§2.2.2.2.10.1)

Equipment Required:

Provide a method of generating two ADS-B transmissions at the minimum interval determined by the ADS-B system implementation. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Note: *The generation of the two closely spaced transmissions may be achieved in a number of possible ways, including: (a) loading the ADS-B system with two ADS-B transmissions that are scheduled for simultaneous transmission (which will result in the second transmission being scheduled for transmission after the first); or (b) configuring/stimulating the system to generate a number of ADS-B transmissions and monitoring the transmissions until random processes schedule two at the minimum spacing.*

Measurement Procedure:

Generate two ADS-B transmissions at the minimum separation that the ADS-B equipment implements. Ensure that the expected ADS-B transmissions occur at the minimum expected spacing. Measure the single pulse having the least RF power output in the two transmissions. Determine that the power output meets the requirements of §2.2.2.2.10.1.

2.4.2.2.10.2 Verification of Class B Equipment RF Peak Output Power (§2.2.2.2.10.2)

Equipment Required:

Provide a method of generating two ADS-B transmissions at the minimum interval determined by the ADS-B system implementation. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Note: *The generation of the two closely spaced transmissions may be achieved in a number of possible ways, including: (a) loading the ADS-B system with two ADS-B transmissions that are scheduled for simultaneous transmission (which will result in the second transmission being scheduled for transmission after the first); or (b) configuring/stimulating the system to generate a number of ADS-B transmissions and monitoring the transmissions until random processes schedule two at the minimum spacing.*

Measurement Procedure:

Generate two ADS-B transmissions at the minimum separation that the ADS-B equipment implements. Ensure that the expected ADS-B transmissions occur at the minimum expected spacing. Measure the single pulse having the least RF power output in the two transmissions. Determine that the power output meets the requirements of §2.2.2.2.10.2.

2.4.2.2.10.3 Verification of RF Peak Output Power (maximum) (§2.2.2.2.10.3)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and ensure that the expected ADS-B transmissions occur. Measure the single pulse having the maximum RF power output. Determine that the maximum power output meets the requirements of §2.2.2.2.10.3.

2.4.2.2.11 Verification of Unwanted Output Power (§2.2.2.2.11)

Equipment Required:

Spectrum Analyzer (HP 8535A, or equivalent). Provide a Directional Coupler (HP 796D, or equivalent).

Notes:

1. *For test equipment protection, the ADS-B transmitter modulation may be disabled by external means.*

2. *This unwanted power requirement should be interpreted as an RF leakage test from the ADS-B transmitter antenna. As such, the ideal implementation would provide a means to disable ADS-B transmissions while maintaining appropriate standby power to the transmitter function. That is, the transmitter is powered but NOT modulated.*

Measurement Procedure:

Ensure that no ADS-B Message data is available to the equipment under test and that there are NO ADS-B Broadcast messages being output.

Record the maximum power output in the range of 1090 MHz plus or minus 3 MHz and determine that the maximum power output meets the requirements of §2.2.2.2.11.

2.4.2.2.12 Verification of Broadcast Rate Capability (§2.2.2.2.12)

Test procedures to validate the broadcast rate capability requirements for the ADS-B transmitted message are provided in §2.4.3.2.7.9 through §2.4.3.3.2.12 of this document.

2.4.3 Verification of Broadcast Message Characteristics (§2.2.3)

No specific test procedure is required to validate §2.2.3.

2.4.3.1 Verification of ADS-B Message Characteristics (§2.2.3.1)

No specific test procedure is required to validate §2.2.3.1, which provides only general information. The ADS-B Message characteristics are tested in the following modulation tests as well as in all tests involving ADS-B Message decoding.

2.4.3.1.1 Verification of ADS-B Message Preamble (§2.2.3.1.1)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Determine Preamble Pulse Spacing

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and verify that the messages are being transmitted by the equipment under test. Display the ADS-B Messages on the oscilloscope. Measure the pulse duration of the first four message pulses. Measure the pulse spacing between the leading edge of the first and each of the second, third and fourth pulses. Determine that the spacing of the pulses is within the tolerances specified in §2.2.3.1.1.

Note: *Interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector. If the detector is not known to be linear, a check should be made to determine the half voltage points.*

2.4.3.1.2 Verification of ADS-B Message Data Pulses (§2.2.3.1.2)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Determine Message Data Pulse Width and Duration

Note: *For tests in this section, unless otherwise specified, examine pulses at the beginning, middle and end of the ADS-B broadcast messages.*

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and verify that the messages are being transmitted by the equipment under test. Measure the pulse duration of the pulses transmitted in the ADS-B Message throughout the message transmission. Determine that the duration of the pulses is within the tolerance specified in §2.2.3.1.2.

Measure the pulse spacing of the fifth reply pulse with reference to the first reply pulse. Determine that the pulse spacing is within the tolerance specified in §2.2.3.1.2.

Note: *Interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector. If the detector is not known to be linear, a check should be made to determine the half voltage points.*

2.4.3.1.3 Verification of ADS-B Message Pulse Shape (§2.2.3.1.3)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Step 1: ADS-B Message Pulse Amplitude Variation (§2.2.3.1.3.a)

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and verify that the messages are being transmitted by the equipment under test. Measure the maximum power differential between pulses in the ADS-B Broadcast Message. Verify that it is within the tolerance specified in §2.2.3.1.3.a.

Step 2: ADS-B Message Pulse Shape (§2.2.3.1.3.b and c)

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and verify that the messages are being transmitted by the equipment under test. Measure the rise and decay time of the ADS-B Broadcast Message pulses. Verify that they are within the tolerances specified in §2.2.3.1.3.b and c.

Note: *Pulse Rise Time is measured as the time interval between 10 percent and 90 percent of peak amplitude on the leading edge of the pulse. Pulse Decay Time is measured as the time interval between 90 percent and 10 percent of peak amplitude on the tailing edge of the pulse. See "Caution" statement below.*

CAUTION: *If the detector is not known to be linear, checks should be made to determine what amplitude points on the detected pulse correspond to the 10 percent and 90 percent amplitude points of the RF pulses. In addition, checks should be made to determine the rise and decay time of the detector.*

Step 3: Frequency Spectrum of ADS-B Message Transmission (§2.2.3.1.3.d)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a Spectrum Analyzer (HP 8535A, or equivalent). Provide a Directional Coupler (HP 796D, or equivalent).

Measurement Procedure:

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and verify that the messages are being transmitted by the equipment under test. Observe the spectral response of the ADS-B Broadcast Message. Verify that it is within the tolerances specified in Table 2-7.

2.4.3.1.4 Verification of ADS-B Message Pulse Spacing (§2.2.3.1.4)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

ADS-B Message Pulse Spacing Tolerance (§2.2.3.1.4)

Load valid Airborne Position data into the ADS-B Transmitting Subsystem and verify that the messages are being output. Determine that the leading edges of the reply pulses are within 50 nanoseconds of their assigned positions.

Note: *Interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector. If the detector is not known to be linear, a check should be made to determine the half voltage points.*

2.4.3.2 Verification of ADS-B and TIS-B Message Baseline Format and Structures (§2.2.3.2)

No specific test procedure is required to validate §2.2.3.2.

2.4.3.2.1 Verification of ADS-B Message Baseline Field Descriptions (§2.2.3.2.1)

No specific test procedure is required to validate §2.2.3.2.1.

2.4.3.2.1.1 Verification of "DF" Downlink Format Field (§2.2.3.2.1.1)

Appropriate test procedures to verify the "DF" field (§2.2.3.2.1.1) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.3.2.1.2 Verification of "CA" Capability Field (used in DF=17) (§2.2.3.2.1.2, §2.2.5.1.3)

Purpose/Introduction:

The "CA" field is a 3-bit field (baseline message bits 6 through 8) used to report the capability of an ADS-B Transmitting Subsystem that is based on a Mode S transponder. The "CA" field is used to report the capability of the ADS-B Transmitting Subsystem and is used in DF=11 and DF=17 transmissions. DF=11 is transmitted in response to an ATCRBS/Mode-S All-Call, Mode-S Only All-Call, and transmitted as an Acquisition Squitter. DF=17 is transmitted as an Extended Squitter. The codes used in the "CA" field are specified in Table 2-8.

The test procedure in §2.4.3.2.1.2.1 **shall** be conducted for all Transponder-Based ADS-B transmitter systems. The "CA" field is set according to the requirements in RTCA DO-181D (EUROCAE ED-73C) and §2.2.3.2.1.2. ADS-B Transmitting Subsystems **shall** determine the On-Ground/Airborne status as specified in §2.2.3.2.1.2 to report the "CA" field reported in transponder replies.

2.4.3.2.1.2.1 Verification of On the Ground Determination (§2.2.3.2.1.2, §2.2.5.1.2, §2.2.5.1.3)

Purpose/Introduction:

This test verifies the correct encoding of the "CA" Capability field in ADS-B transmissions. If an ADS-B Transmitting Subsystem supports both installations with and without automatic means of determining on the ground/airborne status, the following procedures **shall** be conducted for both configurations.

Notes:

1. *Various interface specifications require that Mode S transponder installations provide a means in which the transponder is rendered incapable of generating replies to ATCRBS, ATCRBS/Mode S All Call, and Mode S Only All Call interrogations, but continue to generate Mode S squitter transmissions and continue to reply to discretely addressed Mode S interrogations when the aircraft is on the ground. If this condition is enabled automatically when the aircraft is on the ground, a flight crew switch is not necessary. If performed manually, this condition will have no effect on the transmission of Extended Squitters or on the reporting of the "On-Ground" status (RTCA DO-181D, §2.1.7.b.) (EUROCAE ED-73C, section 2.5). Manual determination of the "On-Ground" status may be achieved through a flight crew switch. Automatic determination of the "On-Ground" status can be achieved through weight on wheels, strut switch, etc.*

2. *Mode-S Transponders should also ensure that all previous TCS commands have been timed out or have been canceled prior to execution of the following procedures (refer to RTCA DO-181D, §2.2.18.2.6 for additional information).*

Measurement Procedure:

Step 1: “CA” Field Verification - No Input Data

The following procedure **shall** be utilized to verify that the “CA” field is properly transmitted in DF=17 messages. For ADS-B Transmitting Subsystems with automatic means of determining the On-Ground status, provide input external to the ADS-B Transmitting Subsystem to indicate on the ground status. For Mode-S Transponder-Based transmitting systems, force the “DR” field equal to zero (0) indicating no downlink requests. Setup the ADS-B Transmitting Subsystem to broadcast Extended Squitters by providing data from the navigation source. After the initiation of Extended Squitters, remove radio altitude, ground speed and airspeed.

For ADS-B systems that have automatic means of determining the On-Ground status, verify that the “CA” Capability field contains a value of FOUR (binary 100) for each Extended Squitter type.

For ADS-B Transmitting Subsystems that do not have automatic means of determining the On-Ground status, verify that the “CA” field equals Six (binary 110) for each Extended Squitter type.

Step 2: “CA” Field Verification – With Input Data

Repeat the above procedure for ADS-B Transmitting Subsystems that have automatic means of determining the On-Ground status. Setup the ADS-B Transmitting Subsystem as in step 1 except provide external input to set the ADS-B Transmitting Subsystem to Airborne status. Verify that the “CA” Capability field reports a value of FIVE (binary 101) for all Extended Squitter types.

Step 3: “CA” Field Verification - Input Data Variation

For Transponder-Based ADS-B Transmitting Subsystems that have automatic detection of the On-the-Ground status and have ground speed, airspeed or radio altitude available, the following procedure applies. For ADS-B Transmitting Subsystems for installations without automatic means of determining the On-the-Ground status, the following procedure **shall** verify that the “CA” field remains set to 6 throughout the procedure.

Set up the ADS-B Transmitting Subsystem as in Step 1 with the On-the-Ground status externally provided to the ADS-B Transmitting Subsystem and additionally provide radio altitude input. Use a value greater than 50 feet. Vary the “Emitter Category” data input through the range of Emitter Category Sets that the system is capable of supporting. Verify that the ADS-B Transmitting Subsystem correctly broadcasts each Extended Squitter message type with the “CA” field equal to 5 for all Emitter Category Set “A” codes 2 through 6 as specified in Table 2-10.

Repeat the procedure given in the previous paragraph, except change the radio altitude data to a value less than 50 feet. Verify for each Extended Squitter type that the reported “CA” field equals 4.

Maintain the radio altitude data at a value less than 50 feet and if the system is capable of accepting ground speed data input, provide ground speed data greater than 100 knots to the ADS-B Transmitting Subsystem. Verify for each Extended Squitter type that the reported "CA" field equals 5 for Emitter Category Set "A," codes 2 through 6.

Maintain the radio altitude data at a value less than 50 feet and set the ground speed to a value less than, or equal to 100 knots. Verify for each Extended Squitter type that the reported "CA" field equals 4.

Maintain the radio altitude data at a value less than 50 feet and the ground speed at 100 knots or less. If the system is capable of accepting airspeed data input, provide airspeed data greater than 100 knots to the ADS-B Transmitting Subsystem. Verify for each Extended Squitter type that the reported "CA" field equals 5 for Emitter category Set "A," codes 2 through 6.

Maintain the radio altitude data at a value less than 50 feet and the ground speed at a value less than or equal to 100 knots. Set the airspeed to a value less than or equal to 100 knots. Verify for each Extended Squitter type that the reported "CA" field equals 4.

Step 4: "CA" Field Verification - Input Data Variation

The following procedure verifies that ADS-B Transmitting Subsystems without automatic detection of "On-The-Ground" status and capable of inputting radio altitude, ground speed, or airspeed, correctly reports "CA" Field equal to SIX (6), even when Surface Position Message broadcast is determined according to the requirements of §2.2.3.2.1.2(c). Set up the ADS-B Transmitting Subsystem as in Step 1 above. For ADS-B Transmitting Subsystems with automatic means of determining "On-The-Ground" status, and capable of inputting radio altitude, ground speed or airspeed, provide external input to set the system to "Airborne" status and verify that the "CA" Field remains equal to FIVE (5) throughout this procedure.

For ADS-B Transmitting Systems capable of accepting radio altitude input, ground speed or airspeed, provide radio altitude data, ground speed and airspeed data to the ADS-B Transmitting Subsystem according to the values defined in Table 2-124 or in the case of no data, stop providing the data as indicated. Verify that the system broadcasts Extended Squitters with the "CA" Field equal to SIX (6) for each test condition in Table 2-124.

2.4.3.2.1.2.2 Verification of Air/Ground Format Selection (§2.2.3.2.1.2, §2.2.5.1.3)

Purpose/Introduction:

The following test **shall** verify that the ADS-B Transmission Device properly selects the Airborne or Surface Message formats for broadcast. The determination is based upon the Air/Ground Status data input for aircraft with automatic means of determining the On-Ground status. Otherwise, the ADS-B Transmitting Subsystem broadcasts Airborne Messages unless the requirements of Table 2-9 are met to emit Surface Position Messages.

Measurement Procedure:

Step 1: Ground Status Verification - No Input Data

For ADS-B Transmitting Subsystems with automatic means of determining the On-Ground status, provide input external to the ADS-B Transmitting Subsystem to indicate the On-Ground status. Setup the ADS-B Transmitting Subsystem to broadcast Extended Squitters by providing data from the navigation source. Provide no radio altitude data, ground speed or airspeed data to the ADS-B Transmitting Subsystem. For ADS-B systems that have automatic means of determining the On-Ground status, verify that the Surface Position Message is broadcast at the proper rate for each Extended Squitter type. For ADS-B Transmitting Subsystems that do not have automatic means of determining the On-Ground status, verify that the system broadcasts Airborne Position and Velocity Messages at the proper rate.

Step 2: Airborne Status Verification – No Input Data

For ADS-B Transmitting Subsystems with automatic means of determining the On-Ground status, provide input external to the ADS-B Transmitting Subsystem to indicate airborne status. Setup the ADS-B Transmitting Subsystem to broadcast Extended Squitters by providing data from the navigation source. Provide no radio altitude, ground speed or airspeed data to the ADS-B Transmitting Subsystem. Verify that Airborne Position and Velocity Messages are broadcast at the proper rate.

Step 3: Air/Ground Status Determination - Input Data Variation

For ADS-B Transmitting Subsystems with automatic means of determining the On-Ground status, provide input external to the ADS-B Transmitting Subsystem to indicate airborne status. Setup the ADS-B Transmitting Subsystem to broadcast Extended Squitters by providing data from the navigation source. Provide Radio Altitude data, ground speed and airspeed data to the ADS-B Transmitting Subsystem according to the values specified in Table 2-124 or in the case of no data, stop providing the data as indicated. For ADS-B Transmitting Subsystems with automatic means of determining the On-Ground status, verify that the ADS-B Transmitting Subsystem broadcasts Airborne Position and Velocity Messages for each run. For ADS-B Transmitting Subsystems without automatic means of determining the On-Ground status, verify that Airborne Position and Velocity Messages or Surface Position Messages as indicated in Table 2-124 are broadcast at the proper rate for each run.

Table 2-124: Air/Ground Status Determination

Test	Emitter Category / Coding	Ground Speed (knots)	Airspeed (knots)	Radio Altitude (feet)	Resulting Air/Ground Status
1	A/2 – 6, B/7	100	100	50	AIRBORNE
2	A/2 – 6, B/7	100	50	25	AIRBORNE
3	A/2 – 6, B/7	50	100	25	AIRBORNE
4	A/2 – 6, B/7	50	50	50	AIRBORNE
5	A/2 – 6, B/7	99	99	49	ON-GROUND
6	A/2 – 6, B/7	50	25	No Data	AIRBORNE
7	A/2 – 6, B/7	25	50	No Data	AIRBORNE
8	A/2 – 6, B/7	49	49	No Data	ON-GROUND
9	A/2 – 6, B/7	No Data	25	No Data	AIRBORNE
10	A/2 – 6, B/7	25	No Data	No Data	AIRBORNE
11	A/2 – 6, B/7	100	No Data	25	AIRBORNE
12	A/2 – 6, B/7	No Data	100	25	AIRBORNE
13	A/2 – 6, B/7	99	No Data	49	ON-GROUND
14	A/2 – 6, B/7	No Data	99	49	ON-GROUND
15	A/2 – 6, B/7	25	No Data	50	AIRBORNE
16	A/2 – 6, B/7	No Data	25	50	AIRBORNE
17	A/2 – 6, B/7	No Data	No Data	25	AIRBORNE
18	A/2 – 6, B/7	No Data	No Data	No Data	AIRBORNE

Step 4: Air/Ground Status Validation – On-Ground Override

For ADS-B Transmitting Subsystems with automatic means of determining the On-Ground status, provide input external to the ADS-B Transmitting Subsystem to indicate ground status. Setup the ADS-B Transmitting Subsystem to broadcast Extended Squitters by providing data from the navigation source. Provide radio altitude data, ground speed and airspeed data to the ADS-B Transmitting Subsystem according to the values specified in Table 2-125 or in the case of no data, stop providing the data as indicated. Verify that Airborne Position and Velocity Messages or Surface Position Messages as indicated in Table 2-125 are broadcast at the proper rate for each run.

Table 2-125: On-Ground Override

Test	Emitter Category / Coding	Ground Speed (knots)	Speed (knots)	Radio Altitude (feet)	Resulting Vertical Status
1	A/2 – 6, B/7	100	100	50	ON-GROUND
2	A/2 – 6, B/7	100	100	51	AIRBORNE
3	A/2 – 6, B/7	100	101	50	AIRBORNE
4	A/2 – 6, B/7	101	100	50	AIRBORNE
5	A/2 – 6, B/7	No Data	100	50	ON-GROUND
6	A/2 – 6, B/7	No Data	100	51	AIRBORNE
7	A/2 – 6, B/7	No Data	101	50	AIRBORNE
8	A/2 – 6, B/7	No Data	No Data	50	ON-GROUND
9	A/2 – 6, B/7	No Data	No Data	51	AIRBORNE
10	A/2 – 6, B/7	100	No Data	50	ON-GROUND
11	A/2 – 6, B/7	101	No Data	50	AIRBORNE
12	A/2 – 6, B/7	100	No Data	51	AIRBORNE
13	A/2 – 6, B/7	100	No Data	No Data	ON-GROUND
14	A/2 – 6, B/7	101	No Data	No Data	AIRBORNE
15	A/2 – 6, B/7	No Data	100	No Data	ON-GROUND
16	A/2 – 6, B/7	No Data	101	No Data	AIRBORNE
17	A/2 – 6, B/7	100	101	No Data	AIRBORNE
18	A/2 – 6, B/7	101	100	No Data	AIRBORNE
19	A/2 – 6, B/7	100	100	No Data	ON-GROUND
20	A/2 – 6, B/7	No Data	No Data	No Data	ON-GROUND

2.4.3.2.1.3 Verification of the "CF" Field (used in DF=18) (§0)

Appropriate test procedures to verify the "CF" field, used in Messages with DF=18, (§0) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.3.2.1.4 Verification of the "AF" Field (used in DF=19) (§2.2.3.2.1.4)

Appropriate test procedures to verify the "AF" field (§2.2.3.2.1.4) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.3.2.1.5 Verification of "AA" Address Field, Announced (§2.2.3.2.1.1, §2.2.5.1.1)

Purpose/Introduction:

The following test **shall** be performed for Non-Transponder-Based Subsystems. The Address Field verification of Transponder-Based Implementations is included in the verification of the "PI" field in §2.4.3.2.1.7. ADS-B Transmitting Subsystems for aircraft installations that are Non-Transponder-Based Implementations output the ICAO 24-Bit Address or the Anonymous Address as determined by the Address Qualifier input.

Measurement Procedure:

The procedure requires configuring the ADS-B Transmitting Subsystem to generate ADS-B Messages to enable capture and bit decoding of the ADS-B Message. The Address Qualifier, ICAO 24-Bit Address, and the Anonymous Address inputs shall be controlled as required by the following steps.

Step 1: Valid Message Contents When Selecting ICAO 24-Bit Address Verification

Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following message content upon decode of the transmitted data:

DF field (Message Bits 1 thru 5) equals 18.
CF field (Message Bits 6 thru 8) equals ZERO.
AA field (Message Bits 9 thru 32) equals AAAAAA {HEX}.

Step 2: Valid Message Contents When Selecting Anonymous Address Verification

Input 555555 {HEX} for the Anonymous Address. Select "Anonymous Address" at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following message content upon decode of the transmitted data:

DF field (Message Bits 1 thru 5) equals 18.
CF field (Message Bits 6 thru 8) equals 1.
AA field (Message Bits 9 thru 32) equals 555555 {HEX}.

2.4.3.2.1.6 Verification of "ME" Message, Extended Squitter (§2.2.3.2.1.6)

No specific test procedure is required to validate §2.2.3.2.1.6.

2.4.3.2.1.7 Verification of "PI" Parity / Identity (§2.2.3.2.1.7, §2.2.5.1.1)

Purpose/Introduction:

The following test **shall** verify that the ADS-B Transmitting Subsystem correctly outputs the Address (AA) field of ADS-B Messages, calculates the proper parity of ADS-B Messages and correctly outputs the PI field in the transmitted ADS-B Messages.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to emit ADS-B Messages having TYPE Code equal to ZERO (0) and no Altitude data. Effectively, establish the messages with the "ME" field set to all ZEROs as indicated in Table 2-126. Refer to Table 2-126 and select the appropriate Set of stimulus to run for the type of equipment being tested as follows:

a. For equipment that can transmit "DF" = 17 and "CA" = 0, use Set 1.

b. For equipment that can transmit "DF" = 17 and "CA" = 4, use Set 2.

c. For equipment that can transmit "DF" = 17 and "CA" = 5, use Set 3.

d. For equipment that can transmit "DF" = 17 and "CA" = 6, use Set 4.

e. For equipment that can transmit "DF" = 17 and "CA" = 7, use Set 5.

f. For equipment that can transmit "DF" = 18 with "CF" = 0, use Set 6. Note that this is the case where the equipment is non-Transponder device.

g. For equipment that can transmit "DF" = 19 with "AF" = 0, use Set 7. Note that this case is where the equipment is for Military Applications.

h. Where an equipment is capable of transmitting several of the cases described in paragraphs "a." through "f.," above, it should suffice that the equipment be testing to only one of the cases since the parity encoding should work the same for all.

For the Set of stimulus given in Table 2-126 that is selected for the equipment under test, establish each of the eight cases by establishing the message having "DF," "CA" or "CF," "AA," and "ME" fields as indicated in Table 2-126.

Note: *Since the ADS-B Transmitting Subsystem may not accept changes in the 24-Bit "AA" field after initial power on, it may be necessary to re-cycle power to the unit under test each time that the 24-Bit "AA" field is changed in this procedure.*

For each case of stimulus provided, verify that the ADS-B Transmitting Subsystem properly generates the associated "PI" code as given in column 6 of Table 2-126.

For Transponder-Based Systems, verify that the "AA" field (i.e., the ICAO 24-Bit Address) cannot be changed once the unit under test has been powered to the operational state.

For Non-Transponder-Based Systems, where a means to change the ICAO 24-bit Address is provided and permitted by the appropriate regulatory authority, verify that the "AA" field (i.e., the ICAO 24-Bit Address) cannot be changed once the unit under test has been powered to the operational state unless the system is in Standby mode as per §4.4.6.

Table 2-126: "PI" Field Encoding

Column #		1	2	3	4	5	6
		Bit #	1 --- 5	6 --- 8	9 -------------- 32	33 -------------- 88	89 ------ 112
SET #	CASE #	Field Name	"DF"	"CA" ("CF")	"AA" [HEX]	"ME" [HEX]	"PI" [HEX]
#1	1		1 0001	000	AA AA AA	ALL ZEROs	46E012
	2		1 0001	000	55 55 55	ALL ZEROs	5B7924
	3		1 0001	000	77 77 77	ALL ZEROs	7DC67B
	4		1 0001	000	BB BB BB	ALL ZEROs	AA45B9
	5		1 0001	000	DD DD DD	ALL ZEROs	C18458
	6		1 0001	000	EE EE EE	ALL ZEROs	B9EAC
	7		1 0001	000	FE DC BA	ALL ZEROs	7790F4
	8		1 0001	000	AB CD EF	ALL ZEROs	7EE5D2
#2	1		1 0001	100	AA AA AA	ALL ZEROs	D8D1FB
	2		1 0001	100	55 55 55	ALL ZEROs	C548CD
	3		1 0001	100	77 77 77	ALL ZEROs	E3F792
	4		1 0001	100	BB BB BB	ALL ZEROs	347450
	5		1 0001	100	DD DD DD	ALL ZEROs	5FB5B1
	6		1 0001	100	EE EE EE	ALL ZEROs	95AF45
	7		1 0001	100	FE DC BA	ALL ZEROs	E9A11D
	8		1 0001	100	AB CD EF	ALL ZEROs	E0D43B
#3	1		1 0001	101	AA AA AA	ALL ZEROs	80A083
	2		1 0001	101	55 55 55	ALL ZEROs	9D39B5
	3		1 0001	101	77 77 77	ALL ZEROs	BB86EA
	4		1 0001	101	BB BB BB	ALL ZEROs	6C0528
	5		1 0001	101	DD DD DD	ALL ZEROs	07C4C9
	6		1 0001	101	EE EE EE	ALL ZEROs	CDDE3D
	7		1 0001	101	FE DC BA	ALL ZEROs	B1DD65
	8		1 0001	101	AB CD EF	ALL ZEROs	B8A543
#4	1		1 0001	110	AA AA AA	ALL ZEROs	68330B
	2		1 0001	110	55 55 55	ALL ZEROs	75AA3D
	3		1 0001	110	77 77 77	ALL ZEROs	531562
	4		1 0001	110	BB BB BB	ALL ZEROs	8496A0
	5		1 0001	110	DD DD DD	ALL ZEROs	EF5741
	6		1 0001	110	EE EE EE	ALL ZEROs	254DB5
	7		1 0001	110	FE DC BA	ALL ZEROs	5943ED
	8		1 0001	110	AB CD EF	ALL ZEROs	5036CB
#5	1		1 0001	111	AA AA AA	ALL ZEROs	304273
	2		1 0001	111	55 55 55	ALL ZEROs	2DDB45
	3		1 0001	111	77 77 77	ALL ZEROs	0B641A
	4		1 0001	111	BB BB BB	ALL ZEROs	DCE7D8
	5		1 0001	111	DD DD DD	ALL ZEROs	B72639
	6		1 0001	111	EE EE EE	ALL ZEROs	7D3CCD
	7		1 0001	111	FE DC BA	ALL ZEROs	013295
	8		1 0001	111	AB CD EF	ALL ZEROs	0847B3
#6	1		1 0010	000	AA AA AA	ALL ZEROs	FDAC76
	2		1 0010	000	55 55 55	ALL ZEROs	E03540
	3		1 0010	000	77 77 77	ALL ZEROs	C68A1F
	4		1 0010	000	BB BB BB	ALL ZEROs	1109DD
	5		1 0010	000	DD DD DD	ALL ZEROs	7AC83C
	6		1 0010	000	EE EE EE	ALL ZEROs	B0D2C8
	7		1 0010	000	FE DC BA	ALL ZEROs	CCDC90
	8		1 0010	000	AB CD EF	ALL ZEROs	C5A9B6
#7	1		1 0011	000	AA AA AA	ALL ZEROs	3E3BAD
	2		1 0011	000	55 55 55	ALL ZEROs	23A29B
	3		1 0011	000	77 77 77	ALL ZEROs	051DC4
	4		1 0011	000	BB BB BB	ALL ZEROs	D29E06
	5		1 0011	000	DD DD DD	ALL ZEROs	B95FE7
	6		1 0011	000	EE EE EE	ALL ZEROs	734513
	7		1 0011	000	FE DC BA	ALL ZEROs	0F4B4B
	8		1 0011	000	AB CD EF	ALL ZEROs	063E6D

2.4.3.2.2 Verification of the Determination of ADS-B and TIS-B Message Types (§2.2.3.2.2)

No specific test procedure is required to validate §2.2.3.2.2.

2.4.3.2.3 Verification of ADS-B Airborne Position Messages (§2.2.3.2.3)

No specific test procedure is required to validate §2.2.3.2.3.

2.4.3.2.3.1 Verification of "TYPE" Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.1)

Purpose/Introduction:

This test procedure verifies that the ADS-B Transmitting Subsystem correctly outputs Airborne Position Messages with the correct TYPE subfield data content in Message Bits 33 through 37 in DF=17 Messages for Transponder-Based Systems and DF=18 Messages for Non-Transponder-Based Systems. The ME field of the ADS-B Airborne Position Message contains the TYPE Code subfield in bits 1 through 5, which along with the Navigation Integrity Category (NIC) Supplement, indicates the navigational integrity of the position information. The ADS-B Transmitting Subsystem determines and outputs the TYPE Code subfield based upon the input it receives from the possible Navigational sources that may interface to the system. The ADS-B Transmitting Subsystem may receive the TYPE Code subfield directly through an external interface instead of dynamically determining the TYPE Code subfield. Whatever the implementation, the test cases must exercise all of the resulting TYPE Code possibilities. If an ADS-B Transmitting Subsystem can only generate a subset of the possible ADS-B Airborne Position Message TYPE Codes, then only those test cases required to produce the possible TYPE Codes **shall** be tested. The test configuration is based on the type(s) of Navigational System(s) that may interface to the ADS-B Transmitting Subsystem and the data it provides.

Measurement Procedure:

Step 1: Verification of TYPE Codes 9 through 18, and 20 through 22 with GNSS/Baro Altitude

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to "Airborne" status. Provide valid non-zero barometric pressure altitude data to the ADS-B System. For each Navigation Integrity Category (NIC) supported, verify that the TYPE Code subfield in the ADS-B Airborne Position Message correctly matches the TYPE Code subfield value from the Radius of Containment (R_C) depicted in Table 2-16. Additionally, verify that the NIC Supplement contained in the Airborne Position Message reflects the proper NIC value contained in Table 2-16 (see §2.4.3.2.7.2.6). The NIC may be derived by the Horizontal Radius of Containment depicted in Table 2-16, or the Horizontal Integrity Limit (HIL), or another means which establishes an appropriate Radius of Containment. To test all of the possible resulting TYPE Codes that could be produced from the Navigational source, degradation of the position data from the Navigation source may require an alarm or alert condition that must be sensed by the ADS-B Transmitting Subsystem. The TYPE Code subfield **shall** contain values in the range from 9 through 18. In the cases where R_C meets the criteria for NIC values of 9, 10 and 11, verify that the proper TYPE Code and NIC Supplement are assigned according to the criteria for each of these NIC values.

Verify that TYPE codes 9 and 10 cannot be set if the unit under test is not provided with either a GNSS Time Mark (see §2.2.5.1.6) or UTC data unless the Non-Coupled Case of position estimation (see §2.2.3.2.3.7.2.2 for Latitude, and §2.2.3.2.3.8.2.2 for Longitude) is implemented.

Note: *UTC data is not acceptable to be used in place of GNSS Time Mark (see §2.2.5.1.6) because of the fact that UTC data may not be available for any possible time up to 200 milliseconds after the leading edge of the GNSS Time Mark. Therefore, UTC data may not be used to establish TYPE Codes 9 and 10.*

Stop providing input of barometric altitude to the ADS-B Transmitting Subsystem and continue providing GNSS Altitude data. If the ADS-B Transmitting Subsystem supports broadcasting TYPE Codes 20 and 21, then verify that the TYPE Code subfield in the ADS-B Airborne Position Message correctly matches the TYPE Code subfield value from the Radius of Containment values depicted in Table 2-16 for TYPE codes 20 and 21. If GNSS Altitude data is provided, but it is not possible to determine the R_C, then verify that the TYPE Code subfield is set to 22.

Verify that TYPE Codes 20 and 21 cannot be set if the unit under test is not provided with either a GNSS Time Mark (see §2.2.5.1.6) or UTC data, unless the Non-Coupled Case of position estimation (see §2.2.3.2.3.7.2.2 for Latitude, and §2.2.3.2.3.8.2.2 for Longitude) is implemented.

Note: *UTC data is not acceptable to be used in place of GNSS Time Mark (see §2.2.5.1.6) because of the fact that UTC data may not be available for any possible time up to 200 milliseconds after the leading edge of the GNSS Time Mark. Therefore, UTC data may not be used to establish TYPE Codes 20 and 21.*

Stop providing inputs of barometric altitude and GNSS altitude to the ADS-B Transmitting Subsystem, and provide position data for each of the R_C values that correspond to the horizontal containment limits for NIC values 0 to 11 (TYPE Codes 9 through 18). Verify that the TYPE Code subfield is 11 and NIC Supplement is ZERO when R_C meets the horizontal containment limits for NIC of 9, 10 and 11. For all other cases, verify that the TYPE Code and the NIC Supplement contain values that correspond to the R_C value depicted in Table 2-16, with the Altitude Subfield set to ALL ZEROs.

Step 2: Verification of TYPE Codes 20 through 22 with GNSS Altitude

This step **shall** be performed for all ADS-B Transmitting Subsystems capable of broadcasting GNSS Altitude data. Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages. Provide both barometric altitude and GNSS altitude data to the ADS-B Transmitting Subsystem. Disconnect the barometric altitude source to the ADS-B Transmitting Subsystem so that only GNSS altitude data is available. For each NIC value supported, verify that the TYPE Code subfield in the ADS-B Airborne Position Message correctly matches the TYPE Code subfield value from the R_C range of values depicted in Table 2-16 for TYPE codes 20 through 22. The TYPE Code may be derived by the R_C depicted in Table 2-16, or the HIL, or another means which establishes an appropriate integrity containment. To test all of the possible resulting TYPE Codes that could be produced from the Navigational source, degradation of the position data from the Navigation source may require an alarm or alert condition that must be sensed by the ADS-B Transmitting Subsystem. Verify that the least capable R_C value of each test case is used to determine the TYPE Code.

Step 3: Verification of TYPE Code if the Radius of Containment is Unavailable

Configure the ADS-B Transmitting Subsystem to "Airborne" status as in Step 1, and provide navigation data from a source that does not provide a valid R_C. Horizontal Containment Radius is valid from a navigation source that provides HPL, HIL, or HPL that can be derived from a RAIM protection threshold. Input both valid barometric altitude and GNSS altitude data. Verify that in the absence of a valid R_C value, the ADS-B Transmitting Subsystem transmits ADS-B Airborne Position Messages with a TYPE Code subfield set to 18.

Stop providing input of valid barometric altitude data to the ADS-B Transmitting Subsystem and continue to provide GNSS altitude data. Verify that the ADS-B Transmitting Subsystem transmits ADS-B Airborne Position Messages with the TYPE Code subfield set to 22.

Stop providing input of valid GNSS altitude data to the ADS-B Transmitting Subsystem. Verify that the ADS-B Transmitting Subsystem transmits ADS-B Airborne Position Messages with the TYPE Code subfield set to ZERO.

2.4.3.2.3.1.1 Verification of Airborne Position Message TYPE Code if Radius of Containment is Available (§2.2.3.2.3.1.1)

Appropriate test procedures are provided in §2.4.3.2.3.1.

2.4.3.2.3.1.2 Verification of Airborne Position Message TYPE Code if Radius of Containment is Not Available (§2.2.3.2.3.1.2)

Appropriate test procedures are provided in §2.4.3.2.3.1.

2.4.3.2.3.1.3 Verification of Special Processing for TYPE Code ZERO (§2.2.3.2.3.1.3)

No specific test procedure is required to validate §2.2.3.2.3.1.3.

2.4.3.2.3.1.3.1 Verification of Significance of TYPE Code Equal to ZERO (§2.2.3.2.3.1.3.1)

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to Airborne status. Provide valid altitude code data and a permanent alert (emergency condition) to the ADS-B Transmitting Subsystem. Connect the GNSS data input and verify that Airborne Position, Velocity and Aircraft Identification Messages are transmitted at the proper rate.

Stop update of the Navigational source of Airborne Latitude and Longitude position information. If the ADS-B Transmitting Subsystem is capable of receiving airborne position data from more than one Navigation source, verify the following by disconnecting each Navigation source separately. Verify that after 2 seconds, the TYPE code of ZERO is transmitted twice per second. Verify that the remaining ME Bits of the message are ZERO, except for the Altitude subfield, and the Surveillance Status subfield. After 60 seconds, verify that the Airborne Position Message continues to be transmitted.

Stop providing valid altitude. After 60 seconds, verify that the Airborne Position Message is no longer transmitted.

Connect the GNSS data input and verify that Airborne Position Messages are broadcast at a nominal rate of 2 per second.

Repeat above if the Latitude and Longitude sources can be received separately. Stop update of Latitude data while maintaining update of Longitude data and verify that TYPE code of ZERO is transmitted twice per second after 2 seconds from data input disconnection.

Repeat above except stop update of Longitude data while maintaining update of Latitude data and verify that TYPE code of ZERO is transmitted twice per second after 2 seconds from data input disconnection.

2.4.3.2.3.1.3.2 Verification of Broadcast of TYPE Code Equal to ZERO (§2.2.3.2.3.1.3.2)

Appropriate test procedures are provided in §2.4.3.2.3.1.3.1.

2.4.3.2.3.1.4 Verification of TYPE Code based on Horizontal Position and Altitude Data (§2.2.3.2.3.1.4)

Appropriate test procedures are provided in §2.4.3.2.3.1.

2.4.3.2.3.2 Verification of "Surveillance Status" Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.2, §2.2.5.1.4)

Purpose/Introduction:

The "Surveillance Status" Subfield (SSS) is contained in ADS-B Airborne Position Messages TYPE Codes 0, 9 through 18, and 20 through 22. The subfield is a 2-bit subfield used to indicate Alert Conditions and SPI Condition utilized in ATCRBS for ATC operations. The alert conditions, as defined, are generated external to the ADS-B Transmitting Subsystem. When an alert condition is generated and appears at the input to the ADS-B Transmitting Subsystem, the SSS **shall** indicate the proper code in the Airborne Position Message, using ME Bits 6 and 7. SSS **shall** be verified for all possible Airborne Position Messages. If the ADS-B Transmitting Subsystem is a Stand Alone Transmitter, and does not have the ability to set SSS, simply verify that SSS is ZERO in all generated Airborne Position Messages.

Measurement Procedure:

Step 1: Verification of "SSS" = "0"

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages. Disconnect the source for Permanent Alert Condition, Temporary Alert Condition and SPI Condition to the ADS-B Transmitting Subsystem. Verify that SSS is ZERO in Airborne Position Messages.

Step 2: Verification of "SSS" = Non "0"

Connect the source(s) for Permanent Alert Condition, Temporary Alert Condition and SPI Condition to the ADS-B Transmitting Subsystem. Input the following conditions:

a. Set the Permanent Alert Condition and verify that "SSS" equals ONE (1) in Airborne Position Messages.

b. Set the Temporary Alert Condition and verify that "SSS" equals TWO (2) in Airborne Position Messages.

c. Ensure Temporary Alert Condition is cleared. Set the SPI Condition and verify that "SSS" equals THREE (3) in Airborne Position Messages.

d. Set the Permanent Alert Condition and the SPI Condition and verify that "SSS" equals ONE (1) in Airborne Position Messages.

e. Set the Temporary Alert Condition and the SPI Condition and verify that "SSS" equals "2" in Airborne Position Messages.

2.4.3.2.3.3 Verification of "NIC Supplement" Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.3)

Measurement Procedure:

Step 1: Verification of NIC Supplement Transmission

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing valid trajectory information at the nominal update rate. Provide the data externally at the interface to the ADS-B system.

Verify that for each input NIC parameter that is specified by the R_C value in Table 2-70, that the system generates ADS-B Airborne Position Messages with the NIC Supplement subfield ("ME" bit 8) set equal to the corresponding binary coding value shown in Table 2-70. Do this for all TYPE Codes in Table 2-70 for Airborne Position Messages.

Step 2: Verification of NIC Supplement – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for NIC Supplement for a period of at least 5 seconds. Verify that ME bit 8 in the Airborne Position Message is set to a value of ZERO (0).

2.4.3.2.3.4 Verification of "Altitude" Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.4)

No specific test procedure is required to validate §2.2.3.2.3.4.

2.4.3.2.3.4.1 Verification of "Barometric Altitude" in ADS-B Airborne Position Messages (§2.2.3.2.3.4.1, §2.2.5.1.5)

Purpose/Introduction:

This test procedure verifies that the Barometric Altitude is reported correctly in ADS-B Messages and that the altitude field reported matches the altitude data at the input interface to the ADS-B Transmitting Subsystem. The Barometric Altitude is reported in the "Altitude" subfield of ADS-B Message TYPE Code 0 and Airborne Position TYPE Codes 9 through 18.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages. If the ADS-B transmitter is based on a Mode S transponder, set the ATS input to the transponder to ZERO.

Step 1: No Barometric Altitude Data

Disconnect the altitude source from the ADS-B Transmitting Subsystem. Verify that all altitude bits (Message Bits 41 through 52, and "ME" Bits 9 through 20) in Airborne Position Messages are set to ZERO.

Step 2: Barometric Altitude Data Available

Connect the Barometric Altitude source to the ADS-B Transmitting Subsystem.

Provide the ADS-B Transmitting Subsystem with the Barometric Altitude Input_A values provided for each case in the following table. Verify that in each case, the "**Q**" bit ("ME" bit 16) is set to ZERO (0).

For each case, verify that the altitude code is properly encoded into the Airborne Position Message Altitude Subfield.

Provide the ADS-B Transmitting Subsystem with the Barometric Altitude Input_B values provided for each case in the following table. Verify that in each case, the "**Q**" bit ("ME" bit 16) is set to ONE (1).

For each case, verify that the altitude code is properly encoded into the Airborne Position Message Altitude Subfield.

Table 2-127: Barometric Altitude Data Inputs

Case #	Altitude Input_A (100 foot increments)	Altitude Input_B (≤ 25 foot increments)
1	- 1000	- 1012
2	- 900	- 500
3	- 200	- 12.5
4	0	0
5	800	18025
6	2800	32050
7	6800	50175
8	14800	50200
9	30800	51600
10	62800	79800

2.4.3.2.3.4.2 Verification of "GNSS Height Above the Ellipsoid (HAE)" in ADS-B Airborne Position Messages (§2.2.3.2.3.4.2)

Purpose/Introduction:

This test procedure verifies that GNSS Height (HAE) is reported correctly in ADS-B Messages and that the altitude field reported is consistent with the GNSS Height (HAE) data at the input interface to the ADS-B Transmitting Subsystem. The GNSS Height (HAE) is reported in the "Altitude" subfield of Airborne Position Messages having TYPE Codes 20 through 22.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages having any TYPE Code between 20 and 22. If the ADS-B transmitter is based on a Mode S transponder, set the ATS input to ONE (1).

Step 1: No GNSS Height (HAE) Data

Disconnect the GNSS Height (HAE) source from the ADS-B Transmitting Subsystem. Verify that all altitude bits (Message Bits 41 through 52, and "ME" Bits 9 through 20) in Airborne Position Messages are set to ZERO.

Step 2: GNSS Height (HAE) Data Available

Connect the GNSS Height (HAE) source to the ADS-B Transmitting Subsystem. Provide the ADS-B Transmitting Subsystem with the GNSS Height (HAE) input values provided for each case in the following table. For each case, verify that the altitude code is properly encoded into the Airborne Position Message Altitude Subfield.

Table 2-128: GNSS Height (HAE) Data Inputs

Case #	GNSS Height (HAE) (≤ 25 foot increments)
1	- 1012
2	- 500
3	- 12.5
4	0
5	18025
6	32050
7	50175
8	50200
9	51600
10	79800

2.4.3.2.3.4.3 Verification of "Altitude Encoding" in ADS-B Airborne Position Messages (§2.2.3.2.3.4.3)

Appropriate test procedures to verify §2.2.3.2.3.4.3 were previously provided in §2.4.3.2.3.4.1 and §2.4.3.2.3.4.2.

2.4.3.2.3.5 Verification of "TIME" (T) Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.5, §2.2.5.1.6, §2.2.5.1.6.1, §2.2.5.1.6.2)

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing position information at the nominal rate. Ensure that the time of applicability of the position data is synchronized to an exact 0.2 second UTC epoch. Verify that the ADS-B Transmitting Subsystem accepts a GNSS TIME MARK, or equivalent input from the navigation data source, which is required in order to be able to update the position data from the navigation data source to an exact 0.2 second UTC epoch. Verify that the "TIME" (T) subfield is set to ONE (1).

If the ADS-B Transmitting Subsystem is not capable of receiving a GNSS Time Mark, or if the input is not available, verify that the "TIME" (T) subfield is set to ZERO (0).

Note: *The ADS-B Transmitting Subsystem must be capable of monitoring the GNSS Time Mark unless the non-coupled case (see §2.2.3.2.4.7.2.2) is implemented.*

2.4.3.2.3.6 Verification of "CPR Format" (F) Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.6)

Appropriate test procedures required to validate §2.2.3.2.3.6 are provided in §2.4.3.2.3.7.1 and §2.4.3.2.3.8.1.

2.4.3.2.3.7 Verification of "Encoded Latitude" Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.6, §2.2.3.2.3.7, §2.2.5.1.7, §2.2.5.1.13, Appendix A.1.7)

Appropriate test procedures required to validate §2.2.3.2.3.7 are provided in §2.4.3.2.3.7.1 through §2.4.3.2.3.7.4.

2.4.3.2.3.7.1 Verification of Airborne Latitude and Longitude Data Encoding (§2.2.3.2.3.6, §2.2.3.2.3.7, §2.2.3.2.3.7.1, §2.2.3.2.3.8, §2.2.3.2.3.8.1, §2.2.5.1.7, §2.2.5.1.8, §2.2.5.1.12, §2.2.5.1.13, Appendix A.1.7)

Purpose/Introduction:

The “Encoded Latitude” subfield is a 17-bit field (ME Bits 23 through 39, Message Bits 55 through 71) containing the encoded latitude of the airborne position. The “Encoded Longitude” subfield is a 17-bit field (ME Bits 40 through 56, Message Bits 72 through 88) containing the encoded longitude of the airborne position. The following test procedure verifies that the ADS-B Transmitting Subsystem correctly receives Latitude and Longitude position data from the Navigation source and outputs encoded Latitude and Longitude data in the Airborne Position Message. The Latitude and Longitude data is encoded according to the Compact Position Reporting (CPR) Format described in Appendix A. The Latitude and Longitude data is dependent upon the positional accuracy supported by the ADS-B Transmitting Subsystem.

The following procedure verifies the ***static*** Latitude and Longitude encoding where the velocity input is 0.0 knots and is intended to verify the actual CPR Latitude and Longitude encoding precision.

Note: *The following procedures are specifically intended to indicate any gross errors in implementation of the CPR encoding algorithm provided in Appendix A.*

Measurement Procedure:

Step 1: Establish Initial Conditions

a. Configure the ADS-B Transmitting Subsystem to create an Airborne Position Message, i.e., TYPE Codes 9 through 18, or 20 through 22.

b. Ensure that the Velocity input provided to the ADS-B Transmitting Subsystem is set to **ZERO**.

Step 2: Verify Encoded Latitude Data

a. Via the appropriate Navigation Data Source interface, provide the ADS-B Transmitting Subsystem with the exact latitude and longitude data pair provided in the Angular Weighted Binary Values Latitude and Longitude Columns for each line item given in Table 2-129.

Provide the latitude and longitude data via the interface at the nominal rate of the navigation data source.

Allow the system to stabilize for at least 2 seconds after the data change prior to continuing with the following steps.

Table 2-129: Airborne Position Encoding Values

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	Latitude HEX	Longitude Decimal	Longitude HEX	Latitude HEX	Longitude HEX	Latitude HEX	Longitude HEX
-90.000000	C0000000	-180.000000	80000000	00000	10000	08000	10000
-89.950000	C0091A2B	179.500000	7FA4FA50	00444	0FF4A	08432	0FF4A
-89.500000	C05B05B0	178.500000	7EEEEEEF	02AAB	0FDDE	0A9F5	0FDDE
-89.000000	C0B60B61	175.500000	7CCCCCCD	05555	0F99A	0D3E9	0F99A
-87.500000	C1C71C72	-165.000000	8AAAAAAB	0D555	11555	151C7	11555
-86.750000	C24FA4FA	-171.500000	860B60B6	11555	0182E	190B6	10C17
-86.500000	C27D27D2	-172.500000	85555555	12AAB	12000	1A5B0	01555
-85.850000	C2F37C05	65.750000	2EC16C17	16222	11889	1DC3B	0BB06
-85.000000	C38E38E4	-142.750000	9A7D27D2	1AAAB	0D3E9	0238E	19EEF
-84.250000	C416C16C	60.000000	2AAAAAAB	1EAAB	1AAAB	0627D	15555
-83.550000	C4962FC9	-60.000000	D5555555	02666	00000	09D3A	05555
-82.680000	C53490BA	120.000000	55555555	070A4	0AAAB	0E63B	00000
-81.750000	C5DDDDDE	-120.000000	AAAAAAAB	0C000	0AAAB	13444	15555
-80.250000	C6EEEEEF	144.000000	66666666	14000	13333	1B222	06666
-79.750000	C749F49F	-144.000000	9999999A	16AAB	00000	1DC17	0CCCD
-78.400000	C83FB72F	-121.000000	A9F49F4A	1DDDE	09B06	04D5E	1471C
-77.400000	C8F5C28F	121.000000	560B60B6	03333	01111	0A148	164FA
-76.550000	C9907F6E	-154.280000	924A2EE0	07BBC	0DB89	0E89B	1B6F4
-75.600000	CA3D70A4	154.280000	6DB5D120	0CCCD	1FFE3	13852	12477
-74.750000	CAD82D83	157.500000	70000000	11555	12000	17FA5	04000
-73.650000	CBA06D3A	-157.500000	90000000	17333	00000	1DBF2	0E000
-72.750000	CC444444	-120.000000	AAAAAAAB	1C000	0AAAB	02777	15555
-71.550000	CD1EB852	120.000000	55555555	02666	00000	08C29	15555
-70.650000	CDC28F5C	-144.000000	9999999A	07333	0CCCD	0D7AE	1999A
-69.550000	CE8ACF13	144.000000	66666666	0D111	00000	133FB	13333
-68.750000	CF1C71C7	-114.550000	AE8ACF13	11555	0A2C6	1771C	145B0
-67.750000	CFD27D28	114.550000	517530ED	16AAB	00024	1CB06	15D3A
-66.550000	D0ACF135	-67.500000	D0000000	1D111	16000	02FB7	1C000
-65.550000	D162FC96	67.500000	30000000	02666	10000	083A0	0A000
-64.450000	D22B3C4D	-83.080000	C4EBBF60	08444	0760B	0DFEE	0EC34
-63.250000	D305B05B	83.080000	3B1440A0	0EAAB	0001D	1449F	189F5
-62.250000	D3BBBBBC	-64.290000	D2485CD8	14000	05B44	19889	0B6B3
-61.250000	D471C71C	64.290000	2DB7A328	19555	0002C	1EC72	1A4BC
-60.250000	D527D27D	-72.000000	CCCCCCCD	1EAAB	06666	0405B	0CCCD
-59.960000	D55C9D78	-120.500000	AA4FA4FA	0036A	0960B	058B1	1416C
-59.955000	D55D867C	120.000000	55555555	003D7	15555	0591C	0AAAB
-59.930000	D5621392	-119.500000	AB05B05B	005F9	01555	05B35	0BF4A
-58.000000	D6C16C17	-78.750000	C8000000	0AAAB	07000	0FD28	0E000
-58.500000	D6666666	78.750000	38000000	08000	19000	0D333	12000
-57.950000	D6CA8642	-22.500000	F0000000	0AEEF	02000	1015A	04000

Table 2-129: Airborne Position Encoding Values (continued)

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	Latitude HEX	Longitude Decimal	Longitude HEX	Latitude HEX	Longitude HEX	Latitude HEX	Longitude HEX
-56.850000	D792C5F9	22.500000	10000000	10CCD	00000	15DA7	1E000
-55.500000	D8888889	-52.940000	DA5A912E	18000	04B59	1CEEF	096A4
-54.620000	D928BB81	52.940000	25A56ED2	1CB18	1FFF1	018C6	1B4A7
-53.250000	DA222222	-30.000000	EAAAAAAB	04000	02AAB	08BBC	05555
-51.950000	DB0ECA86	30.000000	15555555	0AEEF	00000	0F8D1	1D555
-50.750000	DBE93E94	-75.790000	CA1ADA00	11555	06BC3	15D83	0D78D
-49.650000	DCB17E4B	75.790000	35E52600	17333	00007	1B9D0	1943D
-48.250000	DDB05B06	-27.000000	ECCCCCCD	1EAAB	02666	02F4A	04CCD
-47.000000	DE93E93F	27.000000	13333333	05555	00000	0982E	1D99A
-45.600000	DF92C5F9	-68.570000	CF3D3663	0CCCD	0619B	10DA7	0C321
-44.250000	E0888889	-180.000000	80000000	14000	00000	17EEF	10000
-42.850000	E1876543	179.500000	7FA4FA50	1B777	0E16C	1F469	1E222
-41.400000	E28F5C29	178.500000	7EEEEEEF	03333	1A222	06E14	0A444
-40.000000	E38E38E4	175.500000	7CCCCCCD	0AAAB	1E000	0E38E	0E666
-38.500000	E49F49F5	-160.900000	8D950C84	12AAB	0E190	1616C	1C666
-36.900000	E5C28F5C	-171.500000	860B60B6	1B333	1382E	1E7AE	02C17
-35.250000	E6EEEEEF	-172.500000	85555555	04000	00000	07222	0F555
-33.600000	E81B4E82	65.750000	2EC16C17	0CCCD	1E60B	0FC96	18889
-31.800000	E962FC96	-142.750000	9A7D27D2	16666	058E4	193A0	123E9
-30.000000	EAAAAAAB	59.500000	2A4FA4FA	00000	0DBBC	02AAB	0871C
-28.000000	EC16C16C	-60.000000	D5555555	0AAAB	0AAAB	0D27D	10000
-25.900000	ED950C84	-66.700000	D091A2B4	15DDE	05C4D	182B4	0BB2A
-23.600000	EF37C049	-120.000000	AAAAAAAB	02222	00000	043B3	0AAAB
-21.100000	F0FEDCBB	41.500000	1D82D82E	0F777	0AE39	1157A	07333
-18.200000	F30ECA86	-144.000000	9999999A	1EEEF	13333	008D1	00000
-14.900000	F56789AC	-121.000000	A9F49F4A	10889	1AEEF	11DB9	05B06
-10.500000	F8888889	121.000000	560B60B6	08000	0FD28	08EEF	05111
-5.100000	FC5F92C6	6.250000	0471C71C	04CCD	00C72	0540E	0038E
-2.500000	FE38E38E	154.280000	6DB5D120	12AAB	091CE	12E39	1B663
0.000000	00000000	60.000000	2AAAAAAB	00000	1AAAB	00000	15555
0.000000	00000000	-157.500000	90000000	00000	06000	00000	14000
90.000000	40000000	-180.000000	80000000	00000	10000	18000	10000
89.950000	3FF6E5D5	179.500000	7FA4FA50	1FBBC	0FF4A	17BCE	0FF4A
89.500000	3FA4FA50	178.500000	7EEEEEEF	1D555	0FDDE	1560B	0FDDE
89.000000	3F49F49F	175.500000	7CCCCCCD	1AAAB	0F99A	12C17	0F99A
87.500000	3E38E38E	-165.000000	8AAAAAAB	12AAB	11555	0AE39	11555
86.750000	3DB05B06	-171.500000	860B60B6	0EAAB	0182E	06F4A	10C17
86.500000	3D82D82E	-172.500000	85555555	0D555	12000	05A50	01555
85.850000	3D0C83FB	65.750000	2EC16C17	09DDE	11889	023C5	0BB06
85.000000	3C71C71C	-142.750000	9A7D27D2	05555	0D3E9	1DC72	19EEF
84.250000	3BE93E94	60.000000	2AAAAAAB	01555	1AAAB	19D83	15555

Table 2-129: Airborne Position Encoding Values (continued)

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	Latitude HEX	Longitude Decimal	Longitude HEX	Latitude HEX	Longitude HEX	Latitude HEX	Longitude HEX
83.550000	3B69D037	-60.000000	D5555555	1D99A	00000	162C6	05555
82.680000	3ACB6F46	120.000000	55555555	18F5C	0AAAB	119C5	00000
81.750000	3A222222	-120.000000	AAAAAAAB	14000	0AAAB	0CBBC	15555
80.250000	39111111	144.000000	66666666	0C000	13333	04DDE	06666
79.750000	38B60B61	-144.000000	9999999A	09555	00000	023E9	0CCCD
78.400000	37C048D1	-121.000000	A9F49F4A	02222	09B06	1B2A2	1471C
77.400000	370A3D71	121.000000	560B60B6	1CCCD	01111	15EB8	164FA
76.550000	366F8092	-154.280000	924A2EE0	18444	0DB89	11765	1B6F4
75.600000	35C28F5C	154.280000	6DB5D120	13333	1FFE3	0C7AE	12477
74.750000	3527D27D	157.500000	70000000	0EAAB	12000	0805B	04000
73.650000	345F92C6	-157.500000	90000000	08CCD	00000	0240E	0E000
72.750000	33BBBBBC	-120.000000	AAAAAAAB	04000	0AAAB	1D889	15555
71.550000	32E147AE	120.000000	55555555	1D99A	00000	173D7	15555
70.650000	323D70A4	-144.000000	9999999A	18CCD	0CCCD	12852	1999A
69.550000	317530ED	144.000000	66666666	12EEF	00000	0CC05	13333
68.750000	30E38E39	-114.550000	AE8ACF13	0EAAB	0A2C6	088E4	145B0
67.750000	302D82D8	114.550000	517530ED	09555	00024	034FA	15D3A
66.550000	2F530ECB	-67.500000	D0000000	02EEF	16000	1D049	1C000
65.550000	2E9D036A	67.500000	30000000	1D99A	10000	17C60	0A000
64.450000	2DD4C3B3	-83.080000	C4EBBF60	17BBC	0760B	12012	0EC34
63.250000	2CFA4FA5	83.080000	3B1440A0	11555	0001D	0BB61	189F5
62.250000	2C444444	-64.290000	D2485CD8	0C000	05B44	06777	0B6B3
61.250000	2B8E38E4	64.290000	2DB7A328	06AAB	0002C	0138E	1A4BC
60.250000	2AD82D83	-72.000000	CCCCCCCD	01555	06666	1BFA5	0CCCD
59.960000	2AA36288	-120.500000	AA4FA4FA	1FC96	0960B	1A74F	1416C
59.955000	2AA27984	120.000000	55555555	1FC29	15555	1A6E4	0AAAB
59.930000	2A9DEC6E	-119.500000	AB05B05B	1FA07	01555	1A4CB	0BF4A
58.000000	293E93E9	-78.750000	C8000000	15555	07000	102D8	0E000
58.500000	2999999A	78.750000	38000000	18000	19000	12CCD	12000
57.950000	293579BE	-22.500000	F0000000	15111	02000	0FEA6	04000
56.850000	286D3A07	22.500000	10000000	0F333	00000	0A259	1E000
55.500000	27777777	-52.940000	DA5A912E	08000	04B59	03111	096A4
54.620000	26D7447F	52.940000	25A56ED2	034E8	1FFF1	1E73A	1B4A7
53.250000	25DDDDDE	-30.000000	EAAAAAAB	1C000	02AAB	17444	05555
51.950000	24F1357A	30.000000	15555555	15111	00000	1072F	1D555
50.750000	2416C16C	-75.790000	CA1ADA00	0EAAB	06BC3	0A27D	0D78D
49.650000	234E81B5	75.790000	35E52600	08CCD	00007	04630	1943D
48.250000	224FA4FA	-27.000000	ECCCCCCD	01555	02666	1D0B6	04CCD
47.000000	216C16C1	27.000000	13333333	1AAAB	00000	167D2	1D99A
45.600000	206D3A07	-68.570000	CF3D3663	13333	0619B	0F259	0C321
44.250000	1F777777	-180.000000	80000000	0C000	00000	08111	10000

Table 2-129: Airborne Position Encoding Values (continued)

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	Latitude HEX	Longitude Decimal	Longitude HEX	Latitude HEX	Longitude HEX	Latitude HEX	Longitude HEX
42.850000	1E789ABD	179.500000	7FA4FA50	04889	0E16C	00B97	1E222
41.400000	1D70A3D7	178.500000	7EEEEEEF	1CCCD	1A222	191EC	0A444
40.000000	1C71C71C	175.500000	7CCCCCCD	15555	1E000	11C72	0E666
38.500000	1B60B60B	-160.900000	8D950C84	0D555	0E190	09E94	1C666
36.900000	1A3D70A4	-171.500000	860B60B6	04CCD	1382E	01852	02C17
35.250000	19111111	-172.500000	85555555	1C000	00000	18DDE	0F555
33.600000	17E4B17E	65.750000	2EC16C17	13333	1E60B	1036A	18889
31.800000	169D036A	-142.750000	9A7D27D2	0999A	058E4	06C60	123E9
30.000000	15555555	59.500000	2A4FA4FA	00000	0DBBC	1D555	0871C
28.000000	13E93E94	-60.000000	D5555555	15555	0AAAB	12D83	10000
25.900000	126AF37C	-66.700000	D091A2B4	0A222	05C4D	07D4C	0BB2A
23.600000	10C83FB7	-120.000000	AAAAAAAB	1DDDE	00000	1BC4D	0AAAB
21.100000	0F012345	41.500000	1D82D82E	10889	0AE39	0EA86	07333
18.200000	0CF1357A	-144.000000	9999999A	01111	13333	1F72F	00000
14.900000	0A987654	-121.000000	A9F49F4A	0F777	1AEEF	0E247	05B06
10.500000	07777777	121.000000	560B60B6	18000	0FD28	17111	05111
5.100000	03A06D3A	6.250000	0471C71C	1B333	00C72	1ABF2	0038E
2.500000	01C71C72	154.280000	6DB5D120	0D555	091CE	0D1C7	1B663
0.000000	00000000	60.000000	2AAAAAAB	00000	1AAAB	00000	15555
0.000000	00000000	-157.500000	90000000	00000	06000	00000	14000

b. For each Even interval Airborne Position Message that is broadcast by the ADS-B Transmitting Subsystem:

(1). Verify that the “CPR Format” (F) subfield is set to ZERO (0), and

(2). Verify that the Encoded Even Interval Latitude subfield is encoded exactly as shown in the Even Airborne Encoding Latitude column of Table 2-129.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than “1” Least Significant Bit (LSB).

If the encoded value differs from the table value by more than “1” LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

(3). Verify that the Encoded Even Interval Longitude subfield is encoded exactly as shown in the Even Airborne Encoding Longitude column of Table 2-129.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than “1” Least Significant Bit (LSB).

If the encoded value differs from the table value by more than “1” LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

c. For each Odd interval Airborne Position Message that is broadcast by the ADS-B Transmitting Subsystem:

(1). Verify that the “CPR Format” (F) subfield is set to ONE (1), and

(2). Verify that the Encoded Odd Interval Latitude subfield is encoded exactly as shown in the Odd Airborne Encoding Latitude column of Table 2-129.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than “1” Least Significant Bit (LSB).

If the encoded value differs from the table value by more than “1” LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

(3). Verify that the Encoded Odd Interval Longitude subfield is encoded exactly as shown in the Odd Airborne Encoding Longitude column of Table 2-129.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than “1” Least Significant Bit (LSB).

If the encoded value differs from the table value by more than “1” LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

2.4.3.2.3.7.2 Verification of Airborne Latitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 9, 10, 20 and 21) (§2.2.3.2.3.7.2)

Appropriate test procedures are provided in §2.4.3.2.3.7.2.1 and §2.4.3.2.3.7.2.2.

2.4.3.2.3.7.2.1 Verification of GPS/GNSS Time Mark Coupled Case (Extrapolation, “TIME” (T) = “1”) (§2.2.3.2.3.7.2.1)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Airborne Position data when working with GNSS synchronized time.

Equipment Required:

Equipment capable of performing the following:

a. Load all valid data required for the ADS-B Airborne Position Message into the ADS-B Transmitting Subsystem via the operational interfaces.

The equipment should be capable of updating Latitude position and North/South Velocity given time, initial Latitude position, initial North/South Velocity, and North/South acceleration. The Latitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Latitude. Likewise, the North/South Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed N/S Velocity.

The equipment should be capable of updating Longitude position and East/West Velocity given time, initial Longitude position, initial East/West Velocity, and East/West acceleration. The Longitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Longitude. Likewise, the East/West Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed E/W Velocity.

The equipment should be capable of providing position information and velocity information to the ADS-B Transmitting Subsystem at a rate of not less than 5 times per second for each navigation parameter provided.

b. Provide the ADS-B Transmitting Subsystem with an appropriate GNSS Time Mark as described in §2.2.5.1.6.

   The equipment **shall** also be capable of time-tagging the GNSS Time Mark leading edge event to a minimum accuracy of 1.0 millisecond.

c. When providing the GNSS Time Mark described in subparagraph b, above, the equipment **shall** have re-computed position and velocity information required by subparagraph a, above, available at one second intervals that are synchronized with the leading edge of the GNSS Time Mark. Initial delivery of the all new computed position and velocity data to the ADS-B Transmission system **shall** be completed no later than 200 milliseconds after the leading edge of the GNSS Time Mark.

d. The monitoring of transmitted ADS-B Airborne Position Messages and the Airborne Velocity Messages and the extraction of all subfields as may be required. The equipment **shall** also be capable of time-tagging the receipt of any ADS-B Broadcast message to a minimum accuracy of 1.0 milliseconds.

e. Performing local unambiguous CPR decoding of the encoded latitude and longitude subfields in accordance with Appendix A, §A.1.7.4, §A.1.7.5 and §A.1.7.9.

f. After performing the encoded latitude and longitude local unambiguous CPR decoding, the equipment **shall** be capable of computing the difference between the Decoded Latitude Position and the Computed Latitude. Likewise, the equipment **shall** be capable of computing the difference between the Decoded Longitude Position and the Computed Longitude.

g. After extraction of the Velocity subfields from the Airborne Velocity Message, the equipment **shall** compute the difference between the extracted North/South Velocity and the Computed N/S Velocity. Likewise, the equipment **shall** compute the difference between the extracted East/West Velocity and the Computed E/W Velocity.

Measurement Procedure:

Step 1: Equipment Initialization (North-South)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a.	Initialize Time Reference at:	$\mathbf{t_0}$		
	Set initial Computed Longitude to:	45.0	degrees	**WEST**
	Set initial Computed Latitude to:	0.0625	degrees	**NORTH**
	Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Airborne Position Message and the Airborne Velocity Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Latitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from North to South.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees of Latitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Latitude).

c. Select an Airborne Position Message that was received at least 6 seconds after the execution of Step 2 and within 50 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

Verify that the Decoded Latitude Position differs from the Computed Latitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Latitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that the UUT is encoding data correctly in regards to the 0.2 UTC Epochs and in regards to the alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that this capacity is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Velocity Performance (Optional. Apply only if the UUT is estimating or extrapolating velocity)

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Extracted North/South Velocity differs no more than **5%** from the Computed North/South Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Extracted North/South Velocity differs no more than **1%** from the Computed North/South Velocity that was provided to the ADS-B

Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

Step 5: Equipment Re-Initialization (South-North)

Note 1: *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from South to North.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	0.0625	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 6: Performance Check (South-North)

Repeat Steps 2 through 4.

Step 7: Equipment Re-Initialization (North Pole)

Note 1: *Be advised that this test scenario is forcing movement across the North Pole at 1020 knots from South to North. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees North and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	89.9375	degrees	**NORTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 8: Performance Check (North Pole)

Repeat Steps 2 through 4.

Step 9: Equipment Re-Initialization (South Pole)

Note 1: *Be advised that this test scenario is forcing movement across the South Pole at 1020 knots from North to South. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees South and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**WEST**
Set initial Computed Latitude to:	89.9375	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 10: Performance Check (South Pole)

Repeat Steps 2 through 4.

Step 11: Maximum Velocity Performance Checks

Note: *This procedure step must be performed only for those ADS-B Transmitting Subsystems that are expected to be installed in vehicles capable of attaining North/South or East/West velocities in excess of 1022 knots.*

Repeat Steps 1 through 10 with the exception that for each case where the velocity magnitude is specified, set the magnitude to 4,084 knots and the time of test duration should be retained at 35 seconds.

2.4.3.2.3.7.2.2 Verification of Non-Coupled Case (Estimation, "TIME" (T) = "0") (§2.2.3.2.3.7.2.2)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Airborne Position data when NOT working with GNSS synchronized time.

Equipment Required:

Equipment capable of performing the following:

a. Load all valid data required for the ADS-B Airborne Position Message into the ADS-B Transmitting Subsystem via the operational interfaces.

   The equipment should be capable of updating Latitude position and North/South Velocity given time, initial Latitude position, initial North/South Velocity, and North/South acceleration. The Latitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Latitude. Likewise, the North/South Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed N/S Velocity.

   The equipment should be capable of updating Longitude position and East/West Velocity given time, initial Longitude position, initial East/West Velocity, and East/West acceleration. The Longitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Longitude. Likewise, the East/West Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed E/W Velocity.

   The equipment should be capable of providing position information and velocity information to the ADS-B Transmitting Subsystem at a rate of not less than 5 times per second for each navigation parameter provided.

b. Generate an appropriate GNSS Time Mark as described in §2.2.5.1.6, but **DO NOT** apply the GNSS Time Mark to the ADS-B Transmitting Subsystem.

   The equipment **shall** also be capable of time-tagging the GNSS Time Mark leading edge event to a minimum accuracy of 1.0 milliseconds.

c. Referenced to the GNSS Time Mark described in subparagraph b, above, the equipment **shall** have re-computed position and velocity information required by subparagraph a, above, available at one second intervals that are synchronized with the leading edge of the GNSS Time Mark. Initial delivery of the all new computed position and velocity data to the ADS-B Transmission system **shall** be completed no later than 200 milliseconds after the leading edge of the GNSS Time Mark.

d. The monitoring of transmitted ADS-B Airborne Position Messages and the Airborne Velocity Messages and the extraction of all subfields as may be required. The equipment **shall** also be capable of time-tagging the receipt of any ADS-B Broadcast message to a minimum accuracy of 1.0 milliseconds.

e. Performing local unambiguous CPR decoding of the encoded latitude and longitude subfields in accordance with Appendix A, §A.1.7.4, §A.1.7.5 and §A.1.7.9.

f. After performing the encoded latitude and longitude local unambiguous CPR decoding, the equipment **shall** be capable of computing the difference between the Decoded Latitude Position and the Computed Latitude. Likewise, the equipment **shall** be capable of computing the difference between the Decoded Longitude Position and the Computed Longitude.

g. After extraction of the Velocity subfields from the Airborne Velocity Message, the equipment **shall** compute the difference between the extracted North/South Velocity and the Computed N/S Velocity. Likewise, the equipment **shall** compute the difference between the extracted East/West Velocity and the Computed E/W Velocity.

Measurement Procedure:

Step 1: Equipment Initialization (North-South)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a. Initialize Time Reference at: $\mathbf{t_0}$

Set initial Computed Longitude to	45.0	degrees	**WEST**
Set initial Computed Latitude to:	0.0625	degrees	**NORTH**
Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Airborne Position Message and the Airborne Velocity Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Latitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from North to South.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees of Latitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Latitude).

c. Select an Airborne Position Message that was received at least 6 seconds after the execution of Step 2 and within 150 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Latitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that the UUT is encoding data correctly in regards to the 0.2 UTC Epochs and in regards to the alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that this capacity is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Velocity Performance (Optional. Apply only if the UUT is estimating or extrapolating velocity)

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Extracted North/South Velocity differs no more than **5%** from the Computed North/South Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Extracted North/South Velocity differs no more than **1%** from the Computed North/South Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

Step 5: Equipment Re-Initialization (South-North)

Note 1: *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from South to North.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	0.0625	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 6: Performance Check (South-North)

Repeat Steps 2 through 4.

Step 7: Equipment Re-Initialization (North Pole)

Note 1: *Be advised that this test scenario is forcing movement across the North Pole at 1020 knots from South to North. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees North and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	89.9375	degrees	**NORTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 8: Performance Check (North Pole)

Repeat Steps 2 through 4.

Step 9: Equipment Re-Initialization (South Pole)

Note 1: *Be advised that this test scenario is forcing movement across the South Pole at 1020 knots from North to South. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees South and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**WEST**
Set initial Computed Latitude to:	89.9375	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 10: Performance Check (South Pole)

Repeat Steps 2 through 4.

Step 11: Maximum Velocity Performance Checks

Note: *This procedure step must be performed only for those ADS-B Transmitting Subsystems that are expected to be installed in vehicles capable of attaining North/South or East/West velocities in excess of 1022 knots.*

Repeat Steps 1 through 10 with the exception that for each case where the velocity magnitude is specified, set the magnitude to 4,084 knots and the time of test duration should be retained at 35 seconds.

2.4.3.2.3.7.3 Verification of Airborne Latitude Position Extrapolation/Estimation (non - precision) (§2.2.3.2.3.7.3)

Appropriate test procedures are provided in §2.4.3.2.3.7.3.1 and §2.4.3.2.3.7.3.2.

2.4.3.2.3.7.3.1 Verification of Airborne Latitude Position Extrapolation Case (non - precision) (§2.2.3.2.3.7.3.1)

The procedures provided in §2.4.3.2.3.7.2.1 **shall** be used to validate performance of §2.4.3.2.3.7.3.1.

2.4.3.2.3.7.3.2 Verification of Airborne Latitude Position Estimation Case (non - precision) (§2.2.3.2.3.7.3.2)

The procedures provided in §2.4.3.2.3.7.2.2 **shall** be used to validate performance of §2.4.3.2.3.7.3.2.

2.4.3.2.3.7.4 Verification of Airborne Latitude Position Data Retention (§2.2.3.2.3.7.4)

Purpose/Introduction:

The extrapolation or estimation, and update of latitude data fields specified in §2.2.3.2.3.7.2 through §2.2.3.2.3.7.3.2 and **shall** be limited to no more than two seconds, in the event that the latitude position data is no longer available.

At the end of two seconds, the latitude data registers and the encoded latitude field **shall** be set to ALL ZEROs.

Measurement Procedures:

Step 1: Termination of Latitude Data Input - Part 1

Provide normal Airborne Position data to the ADS-B Transmitting Subsystem at the nominal rate. First, filter the data so that the ADS-B Transmitting Subsystem does not receive any latitude data for at least 2 seconds. After 2 seconds, verify that the latitude data registers are set to ALL ZEROs.

Note: *In order to terminate latitude data, it may also be necessary to terminate longitude information since a position fix normally includes both latitude and longitude.*

Step 2: Termination of Latitude Data Input - Part 2

Return to providing normal Airborne Position data at the nominal rate. Next, filter the data so that the device does not receive any latitude data. After 1 second, stop providing data. Verify that after 1 second more, the latitude registers are set to ALL ZEROs.

2.4.3.2.3.8 Verification of "Encoded Longitude" Subfield in ADS-B Airborne Position Messages (§2.2.3.2.3.6, §2.2.3.2.3.8, §2.2.5.1.8, §2.2.5.1.12)

Appropriate test procedures are provided in §2.4.3.2.3.8.1 through §2.4.3.2.3.8.4.

2.4.3.2.3.8.1 Verification of Airborne Longitude Data Encoding (§2.2.3.2.3.8.1, §2.2.5.1.8, §2.2.5.1.12)

Appropriate test procedures to verify the airborne longitude data encoding were previously provided in §2.4.3.2.3.7.1.

2.4.3.2.3.8.2 Airborne Longitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 9, 10, 20 and 21)

Appropriate test procedures are provided in §2.4.3.2.3.8.2.1 and §2.4.3.2.3.8.2.2.

2.4.3.2.3.8.2.1 Verification of GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1") (§2.2.3.2.3.8.2.1)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Airborne Position data when working with GNSS synchronized time.

Equipment Required:

Equipment requirements remain the same as provided in §2.4.3.2.3.7.2.1.

Measurement Procedure:

Step 1: Equipment Initialization (GM-E-W)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a. Initialize Time Reference at: $\mathbf{t_0}$

Set initial Computed Longitude to:	0.0625	degrees	**EAST**
Set initial Computed Latitude to:	45.0	degrees	**NORTH**
Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Airborne Position Message and the Airborne Velocity Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Longitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the Greenwich Meridian by moving across 0 degrees.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

   Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees of Longitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

   Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Longitude).

c. Select an Airborne Position Message that was received at least 6 seconds after the execution of Step 2 and within 50 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

   Verify that the Decoded Longitude Position differs from the Computed Longitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Longitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that the UUT is encoding data correctly in regards to the 0.2 UTC Epochs and in regards to the alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that this capacity is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Velocity Performance (Optional. Apply only if the UUT is estimating or extrapolating velocity)

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Extracted East/West Velocity differs no more than **5%** from the Computed East/West Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Extracted East/West Velocity differs no more than **1%** from the Computed East/West Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

Step 5: Equipment Re-Initialization (GM-W-E)

Note 1: *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from West to East.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	0.0625	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 6: Performance Check (West - East)

Repeat Steps 2 through 4.

Step 7: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**NORTH**
Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 8: Performance Check (IDL-E-W)

Repeat Steps 2 through 4.

Step 9: Equipment Re-Initialization (IDL-W-E)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from West to East. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the International Dateline by moving up to 180 degrees and then down for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**EAST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 10: Performance Check (IDL-W-E)

Repeat Steps 2 through 4.

Step 11: Maximum Velocity Performance Checks

Note: *This procedure step must be performed only for those ADS-B Transmitting Subsystems that are expected to be installed in vehicles capable of attaining North/South or East/West velocities in excess of 1022 knots.*

Repeat Steps 1 through 10 with the exception that for each case where the velocity magnitude is specified, set the magnitude to 4,084 knots and the time of test duration should be retained at 35 seconds.

Step 12: Repeat for additional Navigation Data Sources

Repeat Steps 1 through 11 for each Navigation Data Source input interface that the equipment is designed to accommodate.

2.4.3.2.3.8.2.2 Verification of Non-Coupled Case (Estimation, "TIME" (T) = "0") (§2.2.3.2.3.8.2.2)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Airborne Position data when NOT working with GNSS synchronized time.

Equipment Required:

Equipment requirements remain the same as provided in §2.4.3.2.3.7.2.2.

Measurement Procedure:

Step 1: Equipment Initialization (GM-E-W)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a.	Initialize Time Reference at:	$\mathbf{t_0}$		
	Set initial Computed Longitude to:	0.0625	degrees	**EAST**
	Set initial Computed Latitude to:	45.0	degrees	**NORTH**
	Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Airborne Position Message and the Airborne Velocity Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Longitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the Greenwich Meridian by moving across 0 degrees.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees of Longitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Longitude).

c. Select an Airborne Position Message that was received at least 6 seconds after the execution of Step 2 and within 50 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B

Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

Verify that the Decoded Longitude Position differs from the Computed Longitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **6.375** meters (i.e., approximately 0.000058 degrees of Longitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that UUT is encoding data correctly in regards to 0.2 UTC Epochs and in regards to alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that the capability is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Velocity Performance (Optional. Apply only if the UUT is estimating or extrapolating velocity)

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Extracted East/West Velocity differs no more than **5%** from the Computed East/West Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Extracted East/West Velocity differs no more than **1%** from the Computed East/West Velocity that was provided to the ADS-B Transmitting Subsystem during the GNSS Epoch defined by the leading edge of the GNSS Time Mark delivered to the ADS-B Transmitting Subsystem at least **325** milliseconds prior to the transmission of the Airborne Velocity Message for which the accuracy is being checked.

Step 5: Equipment Re-Initialization (GM-W-E)

Note 1: *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from West to East.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	0.0625	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 6: Performance Check (West - East)

Repeat Steps 2 through 4.

Step 7: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**NORTH**
Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 8: Performance Check (IDL-E-W)

Repeat Steps 2 through 4.

Step 9: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the International Dateline by moving up to 180 degrees and then down for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**EAST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 10: Performance Check (IDL-E-W)

Repeat Steps 2 through 4.

Step 11: Maximum Velocity Performance Checks

Note: *This procedure step must be performed only for those ADS-B Transmitting Subsystems that are expected to be installed in vehicles capable of attaining North/South or East/West velocities in excess of 1022 knots.*

Repeat Steps 1 through 10 with the exception that for each case where the velocity magnitude is specified, set the magnitude to 4,084 knots and the time of test duration should be retained at 35 seconds.

Step 12: Repeat for additional Navigation Data Sources

Repeat Steps 1 through 11 for each Navigation Data Source input interface that the equipment is designed to accommodate.

2.4.3.2.3.8.3 Verification of Airborne Longitude Position Extrapolation/Estimation (non - precision) (§2.2.3.2.3.8.3)

Appropriate test procedures are provided in §2.4.3.2.3.8.3.1 and §2.4.3.2.3.8.3.2.

2.4.3.2.3.8.3.1 Verification of Airborne Longitude Position Extrapolation Case (non - precision) (§2.2.3.2.3.8.3.1)

The procedures provided in §2.4.3.2.3.8.2.1 **shall** be used to validate performance of §2.4.3.2.3.8.3.1.

2.4.3.2.3.8.3.2 Verification of Airborne Longitude Position Estimation Case (non - precision) (§2.2.3.2.3.8.3.2)

The procedures provided in §2.4.3.2.3.8.2.2 **shall** be used to validate performance of §2.4.3.2.3.8.3.2.

2.4.3.2.3.8.4 Verification of Airborne Longitude Position Data Retention (§2.2.3.2.3.8.4)

Measurement Procedure:

Step 1: Longitude Data Termination - Part 1

Provide normal Airborne Position data to the ADS-B Transmitting Subsystem at the nominal rate. First, filter the data so that the ADS-B Transmitting Subsystem does not receive any longitude data for at least 2 seconds. After 2 seconds, verify that the longitude data registers are set to ALL ZEROs.

Note: *In order to terminate longitude data, it may also be necessary to terminate latitude information since a position fix normally includes both latitude and longitude.*

Step 2: Longitude Data Termination - Part 2

Return to providing normal Airborne Position data at the nominal rate. Next, filter the data so that the device does not receive any longitude data. After 1 second, stop providing data. Verify that after 1 second more, the longitude registers are set to ALL ZEROs.

2.4.3.2.4 Verification of ADS-B Surface Position Messages (§2.2.3.2.4)

No specific test procedure is required to validate §2.2.3.2.4.

2.4.3.2.4.1 Verification of "TYPE" Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.1)

Purpose/Introduction:

This test procedure verifies that the ADS-B Transmitting Subsystem correctly outputs ADS-B Surface Position Messages with the correct TYPE Code subfield data content in Message Bits 33 through 37 in DF=17 Messages for Transponder-Based Systems and DF=18 Messages for Non-Transponder-Based Systems. The ME field of the ADS-B Surface Position Message contains the TYPE Code subfield in bits 1 through 5, which, along with the Navigation Integrity Category (NIC) Supplement in the ADS-B Aircraft Operational Status Message (§2.2.3.2.7.2.6), indicates the navigational integrity of the position information. The ADS-B Transmitting Subsystem determines and outputs the TYPE Code subfield based upon the input it receives from the possible Navigational sources that may interface to the system. The ADS-B Transmitting Subsystem may receive the TYPE Code subfield directly through an external interface instead of dynamically determining the TYPE Code subfield. Whatever the implementation, the test cases must exercise all of the resulting TYPE Code possibilities. If an ADS-B Transmitting Subsystem can only generate a subset of the possible ADS-B Surface Position Message TYPE Codes, then only those test cases required to produce the possible TYPE Codes **shall** be tested. The test configuration is based on the type(s) of Navigational System(s) that may interface to the ADS-B Transmitting Subsystem and the data it provides.

Measurement Procedure:

Step 1: Verification of TYPE Codes 5 through 8

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to "On-Ground" status. Provide appropriate Ground Speed information to the ADS-B system in order to establish the high rate of transmission for the ADS-B Surface Position Messages. For each Navigation Integrity Category (NIC) supported, verify that the TYPE Code subfield in the ADS-B Surface Position Message correctly matches the TYPE Code subfield value from the Radius of Containment (R_C) depicted in Table 2-16. Additionally, verify that the NIC Supplement contained in the ADS-B Aircraft Operational Status Message (§2.2.3.2.7.2.6), along with the TYPE Code, reflects the proper NIC value contained in Table 2-16. The TYPE Code may be derived by the Horizontal Radius of Containment depicted in Table 2-16, or the Horizontal Integrity Limit (HIL), or another means which establishes an appropriate Radius of Containment. To test all of the possible resulting TYPE Codes that could be produced from the Navigational source, degradation of the position data from the Navigation source may require an alarm or alert condition that must be sensed by the ADS-B Transmitting Subsystem. The TYPE Code subfield **shall** contain appropriate values in the range from 5 through 8.

Verify that TYPE Codes 5 and 6 cannot be set if the unit under test is not provided with either a GNSS Time Mark (see §2.2.5.1.6) or UTC data unless the Non-Coupled Case of position estimation (see §2.2.3.2.4.7.2.2 for Latitude, and §2.2.3.2.4.8.2.2 for Longitude) is implemented.

Note: *UTC data is not acceptable to be used in place of GNSS Time Mark (see §2.2.5.1.6) because of the fact that UTC data may not be available for any possible time up to 200 milliseconds after the leading edge of the GNSS Time Mark. Therefore, UTC data may not be used to establish TYPE Codes 5 and 6.*

Step 2: Verification of TYPE Codes if the Radius of Containment is Unavailable

Configure the ADS-B Transmitting Subsystem to the "On-Ground" status as in Step 1, and provide navigation data from a source that does not provide a valid R_C value. Horizontal Containment Radius is valid from a navigation source that provides HPL, HIL, or HPL that can be derived from a RAIM protection threshold. Verify that in the absence of a valid R_C value, the ADS-B Transmitting Subsystem transmits ADS-B Surface Position Messages with a TYPE Code subfield set to 8.

2.4.3.2.4.1.1 Verification of Surface Position Message TYPE Code if Containment Radius is Available (§2.2.3.2.4.1.1)

Appropriate test procedures are provided in §2.4.3.2.4.1.

2.4.3.2.4.1.2 Verification of Surface Position Message TYPE Code if Containment Radius is Not Available (§2.2.3.2.4.1.2)

Appropriate test procedures are provided in §2.4.3.2.4.1.

2.4.3.2.4.1.3 Verification of Special Processing for TYPE Code ZERO (§2.2.3.2.3.1.3, §2.2.3.2.4.1.3)

No specific test procedure is required to validate §2.2.3.2.4.1.3.

2.4.3.2.4.1.3.1 Verification of Significance of TYPE Code Equal to ZERO (§2.2.3.2.4.1.3.1)

Purpose/Introduction:

TYPE Code equal to ZERO is broadcast as a result of loss of ADS-B data updates. The following test verifies that the ADS-B Transmitting Subsystem correctly outputs TYPE Code equal to ZERO for each ADS-B Position Message type and correctly terminates the transmission when required.

Measurement Procedure:

Setup the ADS-B Transmitting Subsystem to the On-Ground status. Connect the GNSS data input, provide valid non-zero "Movement" and "Heading/Ground Track" data to the ADS-B System. If the ADS-B Transmitting Subsystem is capable of receiving "Movement" and "Heading/Ground Track" data from a source other than GNSS, then provide such data from the other source. Verify that Surface Position and Aircraft Identification Messages are transmitted at the proper rate.

Stop update of the Navigational source of Latitude and Longitude position information. If the ADS-B Transmitting Subsystem is capable of receiving position data from more than one Navigation source, verify the following by disconnecting each Navigation source separately. Verify that after 2 seconds, the TYPE code is ZERO and the remaining "ME" Bits are ZERO. For Mode S Transponder-Based systems, verify that the Surface Position Message is no longer transmitted after 60 seconds. For Non-Mode S Transponder-Based systems, monitor for 120 seconds and verify that TYPE Code of ZERO is output at the high transmission rate.

2.4.3.2.4.1.3.2 Verification of Broadcast of TYPE Code Equal to ZERO (§2.2.3.2.4.1.3.2)

Appropriate test procedures are provided in §2.4.3.2.4.1.3.1.

2.4.3.2.4.1.4 Verification of TYPE Code based on Horizontal Protection Level or Estimated Horizontal Position Accuracy (§2.2.3.2.4.1.4)

Purpose/Introduction:

This test procedure verifies that if valid horizontal position information is available, then the TYPE Code in the Surface Position Message is set in the range from "5" to "8." If the Horizontal Radius of Containment (R_C) information is available from the navigation data source, the TYPE Code is selected according to the R_C value, in accordance with Table 2-16. If R_C is not available from the navigation data source, then the TYPE Code will be set to 8.

Measurement Procedure:

Step 1: Verification of TYPE Code Based on R_C from the Navigational Data Source

Set the ADS-B Transmitting Subsystem to the "On-Ground" status and enable transmission of Surface Position Messages. Provide valid horizontal position information with an R_C value less than 7.5 m. Verify that the TYPE Code ("ME" bits 1 through 5) in the next transmitted Surface Position Message is set to FIVE (binary 0 0101). Repeat this step with R_C values of less than 75m, less than 0.1 NM (182.5m) and greater than or equal to 0.1 NM (182.5m) and verify that TYPE Codes of 6, 7 and 8 respectively are reflected in each of the respectively next transmitted Surface Position Messages.

Step 2: Verification of TYPE Code 8 if R_C Data is Not Available

Set the ADS-B Transmitting Subsystem to the "On-Ground" status and enable transmission of Surface Position Messages. Provide valid horizontal position information without an R_C value. Verify that the TYPE Code ("ME" bits 1 through 5) in the next transmitted Surface Position Message is set to EIGHT (binary 0 1000).

2.4.3.2.4.2 Verification of "Movement" Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.2)

Purpose/Introduction:

This test procedure will verify that the ADS-B Transmitting Subsystem correctly outputs Surface Position Messages with the correct "Movement" subfield data encoded, in accordance with the encoding provided in Table 2-18, in DF=17 Messages for Transponder-Based Systems, and DF=18 Messages for Non-Transponder-Based Systems.

Measurement Procedure:

Step 1: "Movement" Verification - Part 1

Configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Surface Position Messages at the nominal rate. Set the ADS-B Transmitting Subsystem to "On Ground" status. Provide valid, non-zero "Movement" data to the ADS-B System. Discontinue the "Movement" data and verify that when "Movement" data is not provided to the ADS-B Transmitting Subsystem, the "Movement" subfield is set to ZERO (binary 000 0000).

Step 2: "Movement" Verification - Part 2

Set up the ADS-B Transmitting Subsystem as above and set the "Movement" input to represent a "Movement" of greater than or equal to Zero knots, but less than 0.125 knots. Verify that the "Movement" subfield is set to ONE (binary 000 0001). Increase the "Movement" input to exactly 0.125 knots and verify that the "Movement" subfield is set to TWO (binary 000 0010). Continue to increase the "Movement" input data at increments of 0.125 knots and verify that for each increment for Ground Speed greater than or equal to 0.125 knots and less than 1 knot, the encoding of the "Movement" subfield corresponds to the encoding identified in Table 2-18 representing values between 2 and 8.

Step 3: "Movement" Verification - Part 3

Continue to increase the "Movement" input in increments equal to those identified in Table 2-18 for values greater than or equal to ONE knot and less than 175 knots. Verify that for each such increment, the encoding of the "Movement" subfield is equal to that specified in Table 2-18. Increase the Ground Speed input data to exactly 175 knots and verify that the "Movement" subfield is set to 124. Continue increasing the Ground Speed data input for values greater than 175 knots and verify that the "Movement" subfield continues to be set at 124.

Note: *The last three encodings (125, 126, 127) of the "Movement" subfield in Table 2-18 are reserved to indicate high levels of ground speed change, etc. The precedence of the codes is not defined yet, as inputs that would be required are not currently available.*

2.4.3.2.4.3 Verification of "Status Bit for Heading/Ground Track" Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.3, §2.2.5.1.10)

Purpose/Introduction:

This test procedure will verify that the ADS-B Transmitting Subsystem correctly outputs Surface Position Messages with the correct "Status Bit for Heading/Ground Track" subfield data encoded as specified in Table 2-19 in DF=17 Messages for Transponder-Based Systems and DF=18 Messages for Non-Transponder-Based Systems.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Surface Position Messages at the nominal rate. Set the ADS-B Transmitting Subsystem to "On Ground" status. Provide valid, non-zero "Heading/Ground Track" data to the ADS-B System. Verify that the "Status Bit for Heading/Ground Track" is set to ONE (1). Discontinue the valid "Heading" data and verify that when non-valid "Heading/Ground Track" data is provided to the ADS-B Transmitting Subsystem, that the "Status Bit for Heading/Ground Track" subfield is set to ZERO (0).

2.4.3.2.4.4 Verification of "Heading/Ground Track" Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.4, §2.2.5.1.10)

Purpose/Introduction:

This test procedure will verify that the ADS-B Transmitting Subsystem correctly outputs Surface Position Messages with the correct "Heading/Ground Track" subfield data encoded as specified in Table 2-20, in DF=17 Messages for Transponder-Based Systems and DF=18 Messages for Non-Transponder-Based Systems.

Measurement Procedure:

Step 1: Heading Verification - Part 1

Configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Surface Position Messages at the nominal rate. Set the ADS-B Transmitting Subsystem to "On Ground" status. Provide valid, non-zero "Heading" data to the ADS-B System. Verify that the "Heading" subfield is NOT set to ZERO (0). Set the "Heading" input to exactly ZERO degrees and verify that the encoding of the "Heading" subfield is set to ZERO (binary 000 0000).

Step 2: Heading Verification - Part 2

Raw data used to establish the "Heading" subfield will normally have more resolution (i.e., more bits) than that required by the "Heading" subfield. When converting such data to the "Heading" subfield, the accuracy of the data **shall** be maintained such that it is not worse than ±½ LSB where the LSB is that of the "Heading" subfield.

Set up the ADS-B Transmitting Subsystem as above and set the Heading data input to 2.8125 degrees. Verify that the "Heading" subfield is set to ONE (binary 000 0001). Continue increasing the Heading data input in increments of 2.8125 degrees and verify that for each such increment, the encoding of the "Heading" subfield is set to the corresponding binary code shown in Table 2-20.

2.4.3.2.4.5 Verification of "TIME" (T) Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.5, §2.2.5.1.6)

Measurement Procedure:

If the ADS-B Transmitting Subsystem is capable of synchronizing to a 0.2 second UTC epoch, configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal rate. Ensure that the time of applicability of the position data is synchronized to an exact 0.2 second UTC epoch. Verify that the ADS-B Transmitting Subsystem accepts a GNSS TIME MARK, or equivalent, input from the navigation data source, which is required in order to be able to update the position data from the navigation data source to an exact 0.2 second UTC epoch. Verify that the "TIME" (T) subfield is set to ONE (1).

If the ADS-B Transmitting Subsystem is not capable of synchronizing to a 0.2 second UTC epoch, or if the input is not available, verify that the "TIME" (T) subfield is set to ZERO (0).

Note: *The ADS-B Transmitting Subsystem must be capable of monitoring the GNSS Time Mark unless the non-coupled case (see §2.2.3.2.3.7.2.2) is implemented.*

2.4.3.2.4.6 Verification of "CPR Format" (F) Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.6)

Appropriate procedures to validate §2.2.3.2.4.6 are provided in §2.4.3.2.4.7.1 and §2.4.3.2.4.8.1.

2.4.3.2.4.7 Verification of "Encoded Latitude" Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.6, §2.2.3.2.4.7, §2.2.5.1.7, §2.2.5.1.13, Appendix A.1.7)

Appropriate test procedures are provided in §2.4.3.2.4.7.1 through §2.4.3.2.4.7.4.

2.4.3.2.4.7.1 Verification of Latitude Transition Points and Encoding (§2.2.3.2.4.6, §2.2.3.2.4.7, §2.2.3.2.4.7.1, §2.2.5.1.7, §2.2.5.1.13, Appendix A.1.7)

2.4.3.2.4.7.1.1 Verification of Latitude Transition Points (§2.2.3.2.4.6, §2.2.3.2.4.7, §2.2.3.2.4.7.1, §2.2.5.1.7, §2.2.5.1.13, Appendix A.1.7)

Purpose/Introduction:

This test procedure verifies that the latitude transition points used in CPR encoding are properly computed or established to satisfy the equations provided in Appendix A, §A.1.7.2.d.

Measurement Procedure:

Step 1: Encode Lower Values

a. Set the input longitude value to 45.00 degrees East and keep it at that value for the duration of this test procedure.

b. For each line item in Table 2-130, set the input latitude value to the value provided in the lat_{low} column provided in the table.

c. Verify that the Even Surface Position latitude encoding agrees with the value provided in the "lower latitude" column of the table.

If the latitude encoding does not agree with the table value, proceed to subparagraph d.

Otherwise, verify that the Even Surface Position longitude encoding agrees with the value provided in the "lower longitude" column of the table.

If the Even Surface Position latitude and longitude encoding values agree with the values provided in the "lower latitude" and "lower longitude" columns of the table, then this portion of the test **shall** be considered as PASSED and testing **shall** proceed with Step 2 below.

d. Increase or decrease, as appropriate, the input latitude value until the Surface Position latitude encoding agrees with the value provided in the "lower latitude" column of the table.

Verify that the difference between the input latitude value and the lat_{low} value provided in the table does not exceed $2^{-19} * 10$ degrees.

Verify that the Even Surface Position longitude encoding agrees with the value provided in the "lower longitude" column of the table.

If the Even Surface Position latitude and longitude encoding values agree with the values provided in the "lower latitude" and "lower longitude" columns of the table, then this portion of the test **shall** be considered as PASSED and testing **shall** proceed with Step 2 below.

Step 2: Encode Upper Values

a. Set the input longitude value to 45.00 degrees East and keep it at that value for the duration of this test procedure.

b. For each line item in Table 2-130, set the input latitude value to the value provided in the lat_{up} column provided in the table.

c. Verify that the Even Surface Position latitude encoding agrees with the value provided in the "upper latitude" column of the table.

If the latitude encoding does not agree with the table value, proceed to subparagraph d.

Otherwise, verify that the Even Surface Position longitude encoding agrees with the value provided in the "upper longitude" column of the table.

If the Even Surface Position latitude and longitude encoding values agree with the values provided in the "upper latitude" and "upper longitude" columns of the table, then this portion of the test **shall** be considered as PASSED.

d. Increase or decrease, as appropriate, the input latitude value until the Surface Position latitude encoding agrees with the value provided in the "upper latitude" column of the table.

Verify that the difference between the input latitude value and the lat_{up} value provided in the table does not exceed $2^{-19} * 10$ degrees.

Verify that the Even Surface Position longitude encoding agrees with the value provided in the "upper longitude" column of the table.

If the Even Surface Position latitude and longitude encoding values agree with the values provided in the "upper latitude" and "upper longitude" columns of the table, then this portion of the test **shall** be considered as PASSED.

Table 2-130: Verification of Transition Table

Latitude in degrees (rounded to nearest AWB value)				Even Surface Position Encodings			
lat_{low}	lat_{low}	lat_{up}	lat_{up}	lower		upper	
Decimal	HEX	Decimal	HEX	latitude	longitude	latitude	longitude
10.470463	077216EF	10.470474	07721777	1F5EB	10000	1F5EC	00000
14.828167	0A8B62AB	14.828178	0A8B6333	1C559	00000	1C55A	10000
18.186253	0CEEB4CD	18.186264	0CEEB555	03F93	10000	03F94	00000
21.029388	0EF44889	21.029400	0EF44911	00A08	00000	00A09	10000
23.545040	10BE3E66	23.545052	10BE3EEF	164B5	10000	164B6	00000
25.829247	125E1222	25.829258	125E12AB	07062	00000	07063	10000
27.938976	13DE22AB	27.938988	13DE2333	14081	10000	14082	00000
29.911354	15453222	29.911366	154532AB	1E1BE	00000	1E1BF	10000
31.772095	1697EEEF	31.772106	1697EF77	05CE0	10000	05CE1	00000
33.539932	17D9C222	33.539944	17D9C2AB	0B84C	00000	0B84D	10000
35.228989	190D3DDE	35.229000	190D3E66	0F8D4	10000	0F8D5	00000
36.850250	1A346222	36.850262	1A3462AB	12238	00000	12239	10000
38.412415	1B50C444	38.412426	1B50C4CD	13770	10000	13771	00000
39.922565	1C63AE66	39.922577	1C63AEEF	13AE7	00000	13AE8	10000
41.386517	1D6E2F77	41.386528	1D6E3000	12E99	10000	12E9A	00000
42.809132	1E712A22	42.809143	1E712AAB	1142F	00000	11430	10000
44.194542	1F6D5EEF	44.194553	1F6D5F77	0ED12	10000	0ED13	00000
45.546261	2063719A	45.546272	20637222	0BA75	00000	0BA76	10000
46.867332	2153F000	46.867344	2153F089	07D62	10000	07D63	00000
48.160389	223F54CD	48.160400	223F5555	036BF	00000	036C0	10000
49.427753	23260C44	49.427765	23260CCD	1E757	10000	1E758	00000
50.671497	240876EF	50.671509	24087777	18FDF	00000	18FE0	10000
51.893417	24E6E889	51.893429	24E6E911	130F4	10000	130F5	00000
53.095161	25C1ADDE	53.095173	25C1AE66	0CB26	00000	0CB27	10000
54.278172	26990A22	54.278183	26990AAB	05EF3	10000	05EF4	00000
55.443775	276D3B33	55.443787	276D3BBC	1ECCF	00000	1ECD0	10000
56.593185	283E799A	56.593197	283E7A22	17524	10000	17525	00000
57.727467	290CF6EF	57.727478	290CF777	0F84F	00000	0F850	10000
58.847637	29D8E2AB	58.847649	29D8E333	076A9	10000	076AA	00000
59.954590	2AA26666	59.954601	2AA266EF	1F080	00000	1F081	10000
61.049171	2B69A99A	61.049183	2B69AA22	1661E	10000	1661F	00000
62.132160	2C2ED089	62.132172	2C2ED111	0D7C7	00000	0D7C8	10000
63.204266	2CF1FC44	63.204277	2CF1FCCD	045B9	10000	045BA	00000
64.266163	2DB34C44	64.266174	2DB34CCD	1B02F	00000	1B030	10000
65.318447	2E72DC44	65.318459	2E72DCCD	1175D	10000	1175E	00000
66.361702	2F30C777	66.361713	2F30C800	07B76	00000	07B77	10000
67.396465	2FED26EF	67.396477	2FED2777	1DCA9	10000	1DCAA	00000
68.423218	30A81111	68.423229	30A8119A	13B20	00000	13B21	10000
69.442417	31619B33	69.442429	31619BBC	09703	10000	09704	00000
70.454510	3219DA22	70.454521	3219DAAB	1F079	00000	1F07A	10000
71.459862	32D0DEEF	71.459873	32D0DF77	147A2	10000	147A3	00000
72.458839	3386BAAB	72.458851	3386BB33	09C9E	00000	09C9F	10000
73.451763	343B7C44	73.451775	343B7CCD	1EF89	10000	1EF8A	00000
74.438931	34EF319A	74.438942	34EF3222	1407D	00000	1407E	10000
75.420559	35A1E4CD	75.420570	35A1E555	08F8D	10000	08F8E	00000
76.396843	36539EEF	76.396854	36539F77	1DCCA	00000	1DCCB	10000
77.367886	370464CD	77.367897	37046555	1283D	10000	1283E	00000
78.333733	37B43889	78.333744	37B43911	071EA	00000	071EB	10000
79.294281	38631555	79.294292	386315DE	1B9C8	10000	1B9C9	00000
80.249222	3910ECCD	80.249233	3910ED55	0FFBC	00000	0FFBD	10000
81.198006	39BDA555	81.198017	39BDA5DE	04396	10000	04397	00000
82.139568	3A690D55	82.139580	3A690DDE	184F9	00000	184FA	10000
83.071987	3B12CB33	83.071999	3B12CBBC	0C33D	10000	0C33E	00000
83.991726	3BBA3A22	83.991737	3BBA3AAB	1FD2D	00000	1FD2E	10000
84.891655	3C5E0DDE	84.891666	3C5E0E66	1305A	10000	1305B	00000
85.755409	3CFB4BBC	85.755421	3CFB4C44	0572E	00000	0572F	10000
86.535370	3D894889	86.535381	3D894911	16168	10000	16169	00000
86.999999	3DDDDDDD	87.000011	3DDDDE66	00000	00000	00001	10000

<u>Note to Table 2-130:</u>

An entry from Table 2-130 consists of a pair of latitudes, which, in the process of encoding with maximum precision, will produce values that straddle the transition latitudes as closely as possible. In addition, each entry contains 2 pairs of even surface encodings for the positions at each latitude in the entry and 45 degrees longitude. Both the latitudes and the encodings are distinguished by "upper" and "lower" where the upper position is the one closer to the North Pole.

2.4.3.2.4.7.1.2 Verification of Surface Latitude and Longitude Data Encoding (§2.2.3.2.4.6, §2.2.3.2.4.7, §2.2.3.2.4.7.1, §2.2.3.2.4.8, §2.2.3.2.4.8.1, §2.2.5.1.7, §2.2.5.1.8, §2.2.5.1.12, §2.2.5.1.13, Appendix A.1.7)

<u>Purpose/Introduction:</u>

The “Encoded Latitude” subfield is a 17-bit field (ME Bits 23 through 39, Message Bits 55 through 71) containing the encoded latitude of the surface position. The following test procedure verifies that the ADS-B Transmitting Subsystem correctly receives Latitude position data from the Navigation source and outputs encoded Latitude data in the Surface Position Message. The Latitude data is encoded according to the Compact Position Reporting (CPR) Format described in Appendix A. The Latitude data is dependent upon the positional accuracy supported by the ADS-B Transmitting Subsystem.

The following procedure verifies the ***static*** latitude encoding where the velocity input is 0.0 knots and is intended to verify the actual CPR Latitude encoding precision.

<u>Measurement Procedure:</u>

<u>Step 1:</u> <u>Establish Initial Conditions</u>

a. Configure the ADS-B Transmitting Subsystem to create a Surface Position Message, i.e., TYPE Codes 5 through 8.

b. Ensure that the Velocity input provided to the ADS-B Transmitting Subsystem is set to **ZERO**.

<u>Step 2:</u> <u>Verify Encoded Latitude Data</u>

a. Via the appropriate Navigation Data Source interface, provide the ADS-B Transmitting Subsystem with the exact latitude and longitude data pair provided in the Angular Weighted Binary Values Latitude and Longitude Columns for each line item given in Table 2-131.

Provide the latitude and longitude data via the interface at the nominal rate of the navigation data source.

Allow the system to stabilize for at least 2 seconds after the data change prior to continuing with the following steps.

Table 2-131: Surface Position Encoding Values

Angular Weighted Binary Values (degrees)				Even Surface Encoding		Odd Surface Encoding	
Latitude	Latitude	Longitude	Longitude	Latitude	Longitude	Latitude	Longitude
Decimal	HEX	Decimal	HEX	HEX	HEX	HEX	HEX
-90.000000	C0000000	-180.000000	80000000	00000	00000	00000	00000
-89.950000	C0091A2B	179.500000	7FA4FA50	01111	1FD28	010C8	1FD28
-89.500000	C05B05B0	178.500000	7EEEEEEF	0AAAB	1F777	0A7D2	1F777
-89.000000	C0B60B61	175.500000	7CCCCCCD	15555	1E666	14FA5	1E666
-87.500000	C1C71C72	-165.000000	8AAAAAAB	15555	05555	1471C	05555
-86.750000	C24FA4FA	-171.500000	860B60B6	05555	060B6	042D8	0305B
-86.500000	C27D27D2	-172.500000	85555555	0AAAB	08000	096C1	05555
-85.850000	C2F37C05	65.750000	2EC16C17	18889	06222	170ED	0EC17
-85.000000	C38E38E4	-142.750000	9A7D27D2	0AAAB	14FA5	08E39	07BBC
-84.250000	C416C16C	60.000000	2AAAAAAB	1AAAB	0AAAB	189F5	15555
-83.550000	C4962FC9	-60.000000	D5555555	0999A	00000	074E8	15555
-82.680000	C53490BA	120.000000	55555555	1C28F	0AAAB	198EB	00000
-81.750000	C5DDDDDE	-120.000000	AAAAAAAB	10000	0AAAB	0D111	15555
-80.250000	C6EEEEEF	144.000000	66666666	10000	0CCCD	0C889	1999A
-79.750000	C749F49F	-144.000000	9999999A	1AAAB	00000	1705B	13333
-78.400000	C83FB72F	-121.000000	A9F49F4A	17777	06C17	1357A	11C72
-77.400000	C8F5C28F	121.000000	560B60B6	0CCCD	04444	0851F	193E9
-76.550000	C9907F6E	-154.280000	924A2EE0	1EEEF	16E23	1A26B	0DBD2
-75.600000	CA3D70A4	154.280000	6DB5D120	13333	1FF8B	0E148	091DD
-74.750000	CAD82D83	157.500000	70000000	05555	08000	1FE94	10000
-73.650000	CBA06D3A	-157.500000	90000000	1CCCD	00000	16FC9	18000
-72.750000	CC444444	-120.000000	AAAAAAAB	10000	0AAAB	09DDE	15555
-71.550000	CD1EB852	120.000000	55555555	0999A	00000	030A4	15555
-70.650000	CDC28F5C	-144.000000	9999999A	1CCCD	13333	15EB8	06666
-69.550000	CE8ACF13	144.000000	66666666	14444	00000	0CFEE	0CCCD
-68.750000	CF1C71C7	-114.550000	AE8ACF13	05555	08B18	1DC72	116C1
-67.750000	CFD27D28	114.550000	517530ED	1AAAB	00092	12C17	174E8
-66.550000	D0ACF135	-67.500000	D0000000	14444	18000	0BEDD	10000
-65.550000	D162FC96	67.500000	30000000	0999A	00000	00E82	08000
-64.450000	D22B3C4D	-83.080000	C4EBBF60	01111	1D82E	17FB7	1B0D0
-63.250000	D305B05B	83.080000	3B1440A0	1AAAB	00075	1127D	027D2
-62.250000	D3BBBBBC	-64.290000	D2485CD8	10000	16D0E	06222	0DACB
-61.250000	D471C71C	64.290000	2DB7A328	05555	000AF	1B1C7	092F2
-60.250000	D527D27D	-72.000000	CCCCCCCD	1AAAB	1999A	1016C	13333
-59.960000	D55C9D78	-120.500000	AA4FA4FA	00DA7	0582E	162C2	105B0
-59.955000	D55D867C	120.000000	55555555	00F5C	15555	16470	0AAAB
-59.930000	D5621392	-119.500000	AB05B05B	017E5	05555	16CD4	0FD28
-58.000000	D6C16C17	-78.750000	C8000000	0AAAB	1C000	1F49F	18000
-58.500000	D6666666	78.750000	38000000	00000	04000	14CCD	08000

Table 2-131: Surface Position Encoding Values (continued)

Angular Weighted Binary Values (degrees)				Even Surface Encoding		Odd Surface Encoding	
Latitude	Latitude	Longitude	Longitude	Latitude	Longitude	Latitude	Longitude
Decimal	HEX	Decimal	HEX	HEX	HEX	HEX	HEX
-57.950000	D6CA8642	-22.500000	F0000000	0BBBC	08000	00568	10000
-56.850000	D792C5F9	22.500000	10000000	03333	00000	1769D	18000
-55.500000	D8888889	-52.940000	DA5A912E	00000	12D66	13BBC	05A91
-54.620000	D928BB81	52.940000	25A56ED2	12C60	1FFC6	0631A	0D29A
-53.250000	DA222222	-30.000000	EAAAAAAB	10000	0AAAB	02EEF	15555
-51.950000	DB0ECA86	30.000000	15555555	0BBBC	00000	1E345	15555
-50.750000	DBE93E94	-75.790000	CA1ADA00	05555	1AF0C	1760B	15E35
-49.650000	DCB17E4B	75.790000	35E52600	1CCCD	0001D	0E741	050F4
-48.250000	DDB05B06	-27.000000	ECCCCCCD	1AAAB	0999A	0BD28	13333
-47.000000	DE93E93F	27.000000	13333333	15555	00000	060B6	16666
-45.600000	DF92C5F9	-68.570000	CF3D3663	13333	1866E	0369D	10C84
-44.250000	E0888889	-180.000000	80000000	10000	00000	1FBBC	00000
-42.850000	E1876543	179.500000	7FA4FA50	0DDDE	185B0	1D1A3	18889
-41.400000	E28F5C29	178.500000	7EEEEEEF	0CCCD	08889	1B852	09111
-40.000000	E38E38E4	175.500000	7CCCCCCD	0AAAB	18000	18E39	1999A
-38.500000	E49F49F5	-160.900000	8D950C84	0AAAB	18642	185B0	1199A
-36.900000	E5C28F5C	-171.500000	860B60B6	0CCCD	0E0B6	19EB8	0B05B
-35.250000	E6EEEEEF	-172.500000	85555555	10000	00000	1C889	1D555
-33.600000	E81B4E82	65.750000	2EC16C17	13333	1982E	1F259	02222
-31.800000	E962FC96	-142.750000	9A7D27D2	1999A	1638E	04E82	08FA5
-30.000000	EAAAAAAB	59.500000	2A4FA4FA	00000	16EEF	0AAAB	01C72
-28.000000	EC16C16C	-60.000000	D5555555	0AAAB	0AAAB	149F5	00000
-25.900000	ED950C84	-66.700000	D091A2B4	17777	17135	00ACF	0ECA8
-23.600000	EF37C049	-120.000000	AAAAAAAB	08889	00000	10ECB	0AAAB
-21.100000	F0FEDCBB	41.500000	1D82D82E	1DDDE	0B8E4	055E7	1CCCD
-18.200000	F30ECA86	-144.000000	9999999A	1BBBC	0CCCD	02345	00000
-14.900000	F56789AC	-121.000000	A9F49F4A	02222	0BBBC	076E6	16C17
-10.500000	F8888889	121.000000	560B60B6	00000	1F49F	03BBC	14444
-5.100000	FC5F92C6	6.250000	0471C71C	13333	031C7	15037	00E39
-2.500000	FE38E38E	154.280000	6DB5D120	0AAAB	0473A	0B8E4	0D98B
0.000000	00000000	60.000000	2AAAAAAB	00000	0AAAB	00000	15555
0.000000	00000000	-157.500000	90000000	00000	18000	00000	10000
90.000000	40000000	-180.000000	80000000	00000	00000	00000	00000
89.950000	3FF6E5D5	179.500000	7FA4FA50	1EEEF	1FD28	1EF38	1FD28
89.500000	3FA4FA50	178.500000	7EEEEEEF	15555	1F777	1582E	1F777
89.000000	3F49F49F	175.500000	7CCCCCCD	0AAAB	1E666	0B05B	1E666
87.500000	3E38E38E	-165.000000	8AAAAAAB	0AAAB	05555	0B8E4	05555
86.750000	3DB05B06	-171.500000	860B60B6	1AAAB	060B6	1BD28	0305B
86.500000	3D82D82E	-172.500000	85555555	15555	08000	1693F	05555
85.850000	3D0C83FB	65.750000	2EC16C17	07777	06222	08F13	0EC17
85.000000	3C71C71C	-142.750000	9A7D27D2	15555	14FA5	171C7	07BBC

Table 2-131: Surface Position Encoding Values (continued)

Angular Weighted Binary Values (degrees)				Even Surface Encoding		Odd Surface Encoding	
Latitude	Latitude	Longitude	Longitude	Latitude	Longitude	Latitude	Longitude
Decimal	HEX	Decimal	HEX	HEX	HEX	HEX	HEX
84.250000	3BE93E94	60.000000	2AAAAAAB	05555	0AAAB	0760B	15555
83.550000	3B69D037	-60.000000	D5555555	16666	00000	18B18	15555
82.680000	3ACB6F46	120.000000	55555555	03D71	0AAAB	06715	00000
81.750000	3A222222	-120.000000	AAAAAAAB	10000	0AAAB	12EEF	15555
80.250000	39111111	144.000000	66666666	10000	0CCCD	13777	1999A
79.750000	38B60B61	-144.000000	9999999A	05555	00000	08FA5	13333
78.400000	37C048D1	-121.000000	A9F49F4A	08889	06C17	0CA86	11C72
77.400000	370A3D71	121.000000	560B60B6	13333	04444	17AE1	193E9
76.550000	366F8092	-154.280000	924A2EE0	01111	16E23	05D95	0DBD2
75.600000	35C28F5C	154.280000	6DB5D120	0CCCD	1FF8B	11EB8	091DD
74.750000	3527D27D	157.500000	70000000	1AAAB	08000	0016C	10000
73.650000	345F92C6	-157.500000	90000000	03333	00000	09037	18000
72.750000	33BBBBBC	-120.000000	AAAAAAAB	10000	0AAAB	16222	15555
71.550000	32E147AE	120.000000	55555555	16666	00000	1CF5C	15555
70.650000	323D70A4	-144.000000	9999999A	03333	13333	0A148	06666
69.550000	317530ED	144.000000	66666666	0BBBC	00000	13012	0CCCD
68.750000	30E38E39	-114.550000	AE8ACF13	1AAAB	08B18	0238E	116C1
67.750000	302D82D8	114.550000	517530ED	05555	00092	0D3E9	174E8
66.550000	2F530ECB	-67.500000	D0000000	0BBBC	18000	14123	10000
65.550000	2E9D036A	67.500000	30000000	16666	00000	1F17E	08000
64.450000	2DD4C3B3	-83.080000	C4EBBF60	1EEEF	1D82E	08049	1B0D0
63.250000	2CFA4FA5	83.080000	3B1440A0	05555	00075	0ED83	027D2
62.250000	2C444444	-64.290000	D2485CD8	10000	16D0E	19DDE	0DACB
61.250000	2B8E38E4	64.290000	2DB7A328	1AAAB	000AF	04E39	092F2
60.250000	2AD82D83	-72.000000	CCCCCCCD	05555	1999A	0FE94	13333
59.960000	2AA36288	-120.500000	AA4FA4FA	1F259	0582E	09D3E	105B0
59.955000	2AA27984	120.000000	55555555	1F0A4	15555	09B90	0AAAB
59.930000	2A9DEC6E	-119.500000	AB05B05B	1E81B	05555	0932C	0FD28
58.000000	293E93E9	-78.750000	C8000000	15555	1C000	00B61	18000
58.500000	2999999A	78.750000	38000000	00000	04000	0B333	08000
57.950000	293579BE	-22.500000	F0000000	14444	08000	1FA98	10000
56.850000	286D3A07	22.500000	10000000	1CCCD	00000	08963	18000
55.500000	27777777	-52.940000	DA5A912E	00000	12D66	0C444	05A91
54.620000	26D7447F	52.940000	25A56ED2	0D3A0	1FFC6	19CE6	0D29A
53.250000	25DDDDDE	-30.000000	EAAAAAAB	10000	0AAAB	1D111	15555
51.950000	24F1357A	30.000000	15555555	14444	00000	01CBB	15555
50.750000	2416C16C	-75.790000	CA1ADA00	1AAAB	1AF0C	089F5	15E35
49.650000	234E81B5	75.790000	35E52600	03333	0001D	118BF	050F4
48.250000	224FA4FA	-27.000000	ECCCCCCD	05555	0999A	142D8	13333
47.000000	216C16C1	27.000000	13333333	0AAAB	00000	19F4A	16666
45.600000	206D3A07	-68.570000	CF3D3663	0CCCD	1866E	1C963	10C84

Table 2-131: Surface Position Encoding Values (continued)

Angular Weighted Binary Values (degrees)				Even Surface Encoding		Odd Surface Encoding	
Latitude	Latitude	Longitude	Longitude	Latitude	Longitude	Latitude	Longitude
Decimal	HEX	Decimal	HEX	HEX	HEX	HEX	HEX
44.250000	1F777777	-180.000000	80000000	10000	00000	00444	00000
42.850000	1E789ABD	179.500000	7FA4FA50	12222	185B0	02E5D	18889
41.400000	1D70A3D7	178.500000	7EEEEEEF	13333	08889	047AE	09111
40.000000	1C71C71C	175.500000	7CCCCCCD	15555	18000	071C7	1999A
38.500000	1B60B60B	-160.900000	8D950C84	15555	18642	07A50	1199A
36.900000	1A3D70A4	-171.500000	860B60B6	13333	0E0B6	06148	0B05B
35.250000	19111111	-172.500000	85555555	10000	00000	03777	1D555
33.600000	17E4B17E	65.750000	2EC16C17	0CCCD	1982E	00DA7	02222
31.800000	169D036A	-142.750000	9A7D27D2	06666	1638E	1B17E	08FA5
30.000000	15555555	59.500000	2A4FA4FA	00000	16EEF	15555	01C72
28.000000	13E93E94	-60.000000	D5555555	15555	0AAAB	0B60B	00000
25.900000	126AF37C	-66.700000	D091A2B4	08889	17135	1F531	0ECA8
23.600000	10C83FB7	-120.000000	AAAAAAAB	17777	00000	0F135	0AAAB
21.100000	0F012345	41.500000	1D82D82E	02222	0B8E4	1AA19	1CCCD
18.200000	0CF1357A	-144.000000	9999999A	04444	0CCCD	1DCBB	00000
14.900000	0A987654	-121.000000	A9F49F4A	1DDDE	0BBBC	1891A	16C17
10.500000	07777777	121.000000	560B60B6	00000	1F49F	1C444	14444
5.100000	03A06D3A	6.250000	0471C71C	0CCCD	031C7	0AFC9	00E39
2.500000	01C71C72	154.280000	6DB5D120	15555	0473A	1471C	0D98B
0.000000	00000000	60.000000	2AAAAAAB	00000	0AAAB	00000	15555
0.000000	00000000	-157.500000	90000000	00000	18000	00000	10000

b. For each Even interval Surface Position Message that is broadcast by the ADS-B Transmitting Subsystem:

(1). Verify that the "CPR Format" (F) subfield is set to ZERO (0), and

(2). Verify that the Encoded Even Interval Latitude subfield is encoded exactly as shown in the Even Surface Encoding Latitude column of Table 2-131.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than "1" Least Significant Bit (LSB).

If the encoded value differs from the table value by more than "1" LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

(3). Verify that the Encoded Even Interval Longitude subfield is encoded exactly as shown in the Even Surface Encoding Longitude column of Table 2-131.

If the encoding is not exact, verify that the encoding does not differ from the table value by more that "1" Least Significant Bit (LSB).

If the encoded value differs from the table value by more than "1" LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

c. For each Odd interval Surface Position Message that is broadcast by the ADS-B Transmitting Subsystem:

(1). Verify that the "CPR Format" (F) subfield is set to ONE (1), and

(2). Verify that the Encoded Odd Interval Latitude subfield is encoded exactly as shown in the Odd Surface Encoding Latitude column of Table 2-131.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than "1" Least Significant Bit (LSB).

If the encoded value differs from the table value by more than "1" LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

(3). Verify that the Encoded Odd Interval Longitude subfield is encoded exactly as shown in the Odd Surface Encoding Longitude column of Table 2-131.

If the encoding is not exact, verify that the encoding does not differ from the table value by more than "1" Least Significant Bit (LSB).

If the encoded value differs from the table value by more than "1" LSB, then the test **shall** be considered to have Failed. Otherwise, the test **shall** be considered to have passed.

2.4.3.2.4.7.2 Verification of Surface Latitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 5 and 6) (§2.2.3.2.4.7.2)

Appropriate test procedures are provided in §2.4.3.2.3.7.2.1 and §2.4.3.2.3.7.2.2.

2.4.3.2.4.7.2.1 Verification of GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1") (§2.2.3.2.4.7.2.1, §2.2.5.1.6, §2.2.5.1.7, §2.2.5.1.13)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Surface Position data when working with GNSS synchronized time.

Equipment Required:

Provide equipment capable of performing the following:

a. Load all valid data required for the ADS-B Surface Position Message into the ADS-B Transmitting Subsystem via the operational interfaces.

The equipment should be capable of updating Latitude position and North/South Velocity given time, initial Latitude position, initial North/South Velocity, and

North/South acceleration. The Latitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Latitude. Likewise, the North/South Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed N/S Velocity.

The equipment should be capable of updating Longitude position and East/West Velocity given time, initial Longitude position, initial East/West Velocity, and East/West acceleration. The Longitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Longitude. Likewise, the East/West Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed E/W Velocity.

The equipment should be capable of providing position information and velocity information to the ADS-B Transmitting Subsystem at a rate of not less than 5 times per second for each navigation parameter provided.

b. Provide the ADS-B Transmitting Subsystem with an appropriate GNSS Time Mark as described in §2.2.5.1.6.

   The equipment **shall** also be capable of time-tagging the GNSS Time Mark leading edge event to a minimum accuracy of 1.0 milliseconds.

c. When providing the GNSS Time Mark described in subparagraph b, above, the equipment **shall** have re-computed position and velocity information required by subparagraph a, above, available at one second intervals that are synchronized with the leading edge of the GNSS Time Mark. Initial delivery of the all new computed position and velocity data to the ADS-B Transmission system **shall** be completed no later than 200 milliseconds after the leading edge of the GNSS Time Mark.

d. Monitoring the transmitted ADS-B Surface Position Messages and the Airborne Velocity Messages and extracting all subfields as may be required. The equipment **shall** also be capable of time-tagging the receipt of any ADS-B Broadcast message to a minimum accuracy of 1.0 milliseconds.

e. Performing local unambiguous CPR decoding of the encoded latitude and longitude subfields in accordance with Appendix A, §A.1.7.4, §A.1.7.6 and §A.1.7.9.

f. After performing the encoded latitude and longitude local unambiguous CPR decoding, the equipment **shall** be capable of computing the difference between the Decoded Latitude Position and the Computed Latitude. Likewise, the equipment **shall** be capable of computing the difference between the Decoded Longitude Position and the Computed Longitude.

<u>Measurement Procedure:</u>

<u>Step 1:</u> <u>Equipment Initialization (North-South)</u>

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a. Initialize Time Reference at: $\mathbf{t_0}$

Set initial Computed Longitude to:	45.0	degrees	**WEST**
Set initial Computed Latitude to:	0.0625	degrees	**NORTH**
Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Surface Position Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Latitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from North to South.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees Latitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **3.0** meters (i.e., approximately 0.000027 degrees Latitude).

c. Select a Surface Position Message that was received at least 6 seconds after the execution of Step 2 and within 50 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

Verify that the Decoded Latitude Position differs from the Computed Latitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **3.0** meters (i.e., 0.000027 degrees Latitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that the UUT is encoding data correctly in regards to the 0.2 UTC Epochs and in regards to the alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that this capacity is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding*

Step 4: Equipment Re-Initialization (South-North)

Note 1: *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from South to North.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	0.0625	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 5: Performance Check (South-North)

Repeat Steps 2 through 3.

Step 6: Equipment Re-Initialization (North Pole)

Note 1: *Be advised that this test scenario is forcing movement across the North Pole at 1020 knots from South to North. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees North and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	89.9375	degrees	**NORTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 7: Performance Check (North Pole)

Repeat Steps 2 through 3.

Step 8: Equipment Re-Initialization (South Pole)

Note 1: *Be advised that this test scenario is forcing movement across the South Pole at 1020 knots from North to South. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees South and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**WEST**
Set initial Computed Latitude to:	89.9375	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 9: Performance Check (South Pole)

Repeat Steps 2 through 3.

Step 10: Repeat for additional Navigation Data Sources

Repeat Steps 1 through 9 for each Navigation Data Source input interface that the equipment is designed to accommodate.

2.4.3.2.4.7.2.2 Verification of Non-Coupled Case (Estimation, "TIME" (T) = "0") (§2.2.3.2.4.7.2.2, §2.2.5.1.7, §2.2.5.1.13)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Surface Position data when NOT working with GNSS synchronized time.

Equipment Required:

Provide equipment capable of performing the following:

a. Load all valid data required for the ADS-B Surface Position Message into the ADS-B Transmitting Subsystem via the operational interfaces.

   The equipment should be capable of updating Latitude position and North/South Velocity given time, initial Latitude position, initial North/South Velocity, and North/South acceleration. The Latitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Latitude. Likewise, the North/South Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed N/S Velocity.

   The equipment should be capable of updating Longitude position and East/West Velocity given time, initial Longitude position, initial East/West Velocity, and East/West acceleration. The Longitude Position provided to the ADS-B Transmission system **shall** be referred to as the Computed Longitude. Likewise, the East/West Velocity provided to the ADS-B Transmission system **shall** be referred to as the Computed E/W Velocity.

   The equipment should be capable of providing position information and velocity information to the ADS-B Transmitting Subsystem at a rate of not less than 5 times per second for each navigation parameter provided.

b. Generate an appropriate GNSS Time Mark as described in §2.2.5.1.6 but **DO NOT** apply the GNSS Time Mark to the ADS-B Transmitting Subsystem.

   The equipment **shall** also be capable of time-tagging the GNSS Time Mark leading edge event to a minimum accuracy of 1.0 milliseconds.

c. Referenced to the GNSS Time Mark described in subparagraph b, above, the equipment **shall** have re-computed position and velocity information required by subparagraph a, above, available at one second intervals that are synchronized with the leading edge of the GNSS Time Mark. Initial delivery of the all new computed position and velocity data to the ADS-B Transmission system **shall** be completed no later than 200 milliseconds after the leading edge of the GNSS Time Mark.

d. Monitoring the transmitted ADS-B Surface Position Messages and the Airborne Velocity Messages and extracting all subfields as may be required. The equipment **shall** also be capable of time-tagging the receipt of any ADS-B Broadcast message to a minimum accuracy of 1.0 milliseconds.

e. Performing local unambiguous CPR decoding of the encoded latitude and longitude subfields in accordance with Appendix A, §A.1.7.4, §A.1.7.5 and §A.1.7.9.

f. After performing the encoded latitude and longitude local unambiguous CPR decoding, the equipment **shall** be capable of computing the difference between the Decoded Latitude Position and the Computed Latitude. Likewise, the equipment **shall** be capable of computing the difference between the Decoded Longitude Position and the Computed Longitude.

Measurement Procedure:

Step 1: Equipment Initialization (North-South)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a.	Initialize Time Reference at:	$\mathbf{t_0}$		
	Set initial Computed Longitude to:	45.0	degrees	**WEST**
	Set initial Computed Latitude to:	0.0625	degrees	**NORTH**
	Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Surface Position Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Latitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from North to South.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees Latitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position by no more than **3.0** meters (i.e., approximately 0.000027 degrees Latitude).

c. Select a Surface Position Message that was received within 150 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

   Verify that the Decoded Latitude Position differs from the Computed Latitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **3.0** meters (i.e., 0.000027 degrees Latitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that UUT is encoding data correctly in regards to 0.2 UTC Epochs and in regards to alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that the capability is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Equipment Re-Initialization (South-North)

Note 1: *Be advised that this test scenario is forcing movement across the Equator at 1020 knots from South to North.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	0.0625	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 5: Performance Check (South-North)

Repeat Steps 2 through 4.

Step 6: Equipment Re-Initialization (North Pole)

Note 1: *Be advised that this test scenario is forcing movement across the North Pole at 1020 knots from South to North. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees North and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**EAST**
Set initial Computed Latitude to:	89.9375	degrees	**NORTH**
Set initial Computed N/S Velocity to:	1020	knots	**NORTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 7: Performance Check (North Pole)

Repeat Steps 2 through 4.

Step 8: Equipment Re-Initialization (South Pole)

Note 1: *Be advised that this test scenario is forcing movement across the South Pole at 1020 knots from North to South. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the pole by moving up to 90.0 degrees South and then down from the pole for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	45.0	degrees	**WEST**
Set initial Computed Latitude to:	89.9375	degrees	**SOUTH**
Set initial Computed N/S Velocity to:	1020	knots	**SOUTH**

Note 2: *The velocity requirements above are specified in terms of North/South velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the North/South Velocity required in the transmitted messages.*

Step 9: Performance Check (South Pole)

Repeat Steps 2 through 4.

Step 10: Repeat for additional Navigation Data Sources

Repeat Steps 1 through 9 for each Navigation Data Source input interface that the equipment is designed to accommodate.

2.4.3.2.4.7.3 Verification of Surface Latitude Position Extrapolation/Estimation (non - precision) (§2.2.3.2.4.7.3)

Appropriate test procedures are provided in §2.4.3.2.4.7.3.1 and §2.4.3.2.4.7.3.2.

2.4.3.2.4.7.3.1 Verification of Surface Latitude Position Extrapolation Case (non - precision) (§2.2.3.2.4.7.3.1)

The test procedures provided in §2.4.3.2.4.7.2.1 **shall** be used to validate performance of §2.4.3.2.4.7.3.1.

2.4.3.2.4.7.3.2 Verification of Surface Latitude Position Estimation Case (non - precision) (§2.2.3.2.4.7.3.2)

The test procedures provided in §2.4.3.2.4.7.2.2 **shall** be used to validate performance of §2.4.3.2.4.7.3.2.

2.4.3.2.4.7.4 Verification of Surface Latitude Position Data Retention (§2.2.3.2.4.7.4, §2.2.5.1.7)

Purpose/Introduction:

The extrapolation or estimation, and update of latitude data and fields specified in §2.2.3.2.4.7.2 through §2.2.3.2.4.7.3.2 **shall** be limited to no more than two seconds, in the event that the latitude position data is no longer available. At the end of two seconds, the latitude data registers and the encoded latitude field **shall** be set to ALL ZEROs.

Measurement Procedures:

Step 1: Termination of Latitude Data Input - Part 1

Provide normal Surface Position data to the ADS-B Transmitting Subsystem at the nominal rate. First, filter the data so that the ADS-B Transmitting Subsystem does not receive any latitude data for at least 2 seconds. After 2 seconds, verify that the latitude data registers are set to ALL ZEROs.

Note: *In order to terminate latitude data, it may also be necessary to terminate longitude information since a position fix normally includes both latitude and longitude.*

Step 2: Termination of Latitude Data Input - Part 2

For equipment that can independently filter latitude and longitude, return to providing normal Surface Position data at the nominal rate. Next, filter the data so that the device does not receive any latitude data. After 1 second, stop providing data. Verify that after 1 second more, the latitude registers are set to ALL ZEROs.

2.4.3.2.4.8 Verification of "Encoded Longitude" Subfield in ADS-B Surface Position Messages (§2.2.3.2.4.6, §2.2.3.2.4.8, §2.2.5.1.6, §2.2.5.1.8, §2.2.5.1.13)

Appropriate test procedures are provided in §2.4.3.2.4.8 through §2.4.3.2.4.8.4.

2.4.3.2.4.8.1 Verification of Surface Longitude Data Encoding (§2.2.3.2.4.8.1, §2.2.5.1.8, §2.2.5.1.13)

Appropriate test procedures to verify the surface longitude data encoding were previously provided in §2.4.3.2.4.7.1.2.

2.4.3.2.4.8.2 Verification of Surface Longitude Position Extrapolation/Estimation (Precision Case, TYPE Codes 5 and 6) (§2.2.3.2.4.8.2)

Appropriate test procedures are provided in §2.4.3.2.4.8.2.1 and §2.4.3.2.4.8.2.2.

2.4.3.2.4.8.2.1 Verification of GPS/GNSS Time Mark Coupled Case (Extrapolation, "TIME" (T) = "1") (§2.2.3.2.4.8.2.1, §2.2.5.1.6, §2.2.5.1.8, §2.2.5.1.13)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Surface Position data when working with GNSS synchronized time.

Equipment Required:

Equipment requirements remain the same as provided in §2.4.3.2.4.7.2.1.

Measurement Procedure:

Step 1: Equipment Initialization (GM-E-W)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a. Initialize Time Reference at: $\mathbf{t_0}$

Set initial Computed Longitude to:	0.0625	degrees	**EAST**
Set initial Computed Latitude to:	45.0	degrees	**NORTH**
Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Surface Position Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Longitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the International Dateline by moving up to 180 degrees and then down for the duration of the test.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

   Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees Longitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

   Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **3.0** meters (i.e., approximately 0.000027 degree Longitude).

c. Select a Surface Position Message that was received at least 6 seconds after the execution of Step 2 and within 50 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

   Verify that the Decoded Longitude Position differs from the Computed Longitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **3.0** meters (i.e., approximately 0.000027 degrees Longitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that the UUT is encoding data correctly in regards to the 0.2 UTC Epochs and in regards to the alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that this capacity is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Equipment Re-Initialization (GM-W-E)

Note 1: *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from West to East.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	0.0625	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 5: Performance Check (West - East)

Repeat Steps 2 through 3.

Step 6: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**NORTH**
Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 7: Performance Check (IDL-E-W)

Repeat Steps 2 through 3.

Step 8: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the International Dateline by moving up to 180 degrees and then down for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**EAST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 9: Performance Check (IDL-E-W)

Repeat Steps 2 through 3.

Step 10: Repeat for additional Navigation Data Sources

Repeat Steps 1 through 9 for each Navigation Data Source input interface that the equipment is designed to accommodate.

2.4.3.2.4.8.2.2 Verification of Non-Coupled Case (Estimation, "TIME" (T) = "0") (§2.2.3.2.4.8.2.2, §2.2.5.1.8, §2.2.5.1.13)

Purpose/Introduction:

This test procedure will be used to verify that the ADS-B Transmitting Subsystem correctly extrapolates and encodes Surface Position data when NOT working with GNSS synchronized time.

Equipment Required:

Equipment requirements remain the same as provided in §2.4.3.2.4.7.2.2.

Measurement Procedure:

Step 1: Equipment Initialization (GM-E-W)

Initialize the equipment to provide the following to the ADS-B Transmitting Subsystem.

DO NOT START DELIVERY OF THE DATA AT THIS TIME

a.	Initialize Time Reference at:	$\mathbf{t_0}$		
	Set initial Computed Longitude to:	0.0625	degrees	**EAST**
	Set initial Computed Latitude to:	45.0	degrees	**NORTH**
	Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

b. GNSS Time Mark as described above under Equipment subparagraphs b and c.

c. All other data required to generate the Airborne Position Message and the Airborne Velocity Message.

Step 2: Equipment Data Delivery Start Up

Allow the equipment to start delivery of the data specified in Step 1 and designate this time as $\mathbf{t_0}$. Continue to let the equipment provide the data for at least 35 seconds.

Step 3: Longitude Position Performance

Notes:

1. *Since there has been no position or velocity data provided to the ADS-B Transmitting Subsystem up to this time (at least for the purposes of this test procedure), a minimal amount of time will need to be allowed for the transmitted message data to stabilize. This fact has been factored in to the following required response criteria.*

2. *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the International Dateline by moving up to 180 degrees and then down for the duration of the test.*

a. At 4.0 ±0.005 seconds after executing Step 2 where data has started being provided to the ADS-B Transmitting Subsystem under test:

Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **22.1** meters (i.e., approximately 0.0002 degrees Longitude).

b. At all successive points during the time of test that occur at least 6 seconds after the execution of Step 2:

Verify that the Decoded Longitude Position differs from the Computed Longitude Position by no more than **3.0** meters (i.e., approximately 0.000027 degrees Longitude).

c. Select an Airborne Position Message that was received at least 6 seconds after the execution of Step 2 and within 50 ±25 milliseconds of a GNSS Time Mark generated by the Test Equipment and provided to the ADS-B Transmitting Subsystem. Designate the leading edge of the GNSS Time Mark as $\mathbf{t_1}$.

Verify that the Decoded Longitude Position differs from the Computed Longitude Position at time $\mathbf{t_1}$ **+ 200 milliseconds** by no more than **3.0** meters (i.e., approximately 0.000027 degrees Longitude).

d. Verify that the received message was encoded in the proper format, i.e., odd or even encoding, by correlating the received message to the stimulus data provided by the test equipment.

Note: *This test is intended to demonstrate that UUT is encoding data correctly in regards to 0.2 UTC Epochs and in regards to alternating odd and even encodings. Since the test set knows what the data is at given 1.0 second intervals, and it also time tags the received data, it is reasonable to expect that the capability is adequate to establish the proper 0.2 UTC Epochs and the appropriate format encoding.*

Step 4: Equipment Re-Initialization (GM-W-E)

Note 1: *Be advised that this test scenario is forcing movement across the Greenwich Meridian at 1020 knots from West to East.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	0.0625	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 5: Performance Check (West - East)

Repeat Steps 2 through 3.

Step 6: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**WEST**
Set initial Computed Latitude to:	45.0	degrees	**NORTH**
Set initial Computed E/W Velocity to:	1020	knots	**WEST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 7: Performance Check (IDL-E-W)

Repeat Steps 2 through 3.

Step 8: Equipment Re-Initialization (IDL-E-W)

Note 1: *Be advised that this test scenario is forcing movement across the International Dateline at 1020 knots from East to West. It is up to the equipment designers to insure that equipment under test and the test equipment properly move across the International Dateline by moving up to 180 degrees and then down for the duration of the test.*

Repeat Step 1 with the following equipment settings:

Initialize Time Reference at:	$\mathbf{t_0}$		
Set initial Computed Longitude to:	179.9375	degrees	**EAST**
Set initial Computed Latitude to:	45.0	degrees	**SOUTH**
Set initial Computed E/W Velocity to:	1020	knots	**EAST**

Note 2: *The velocity requirements above are specified in terms of East/West velocities. If alternate velocity and direction sources are used, i.e., ground speed and ground track, then it is up to the implementer to verify that such information is properly resolved into the East/West Velocity required in the transmitted messages.*

Step 9: Performance Check (IDL-E-W)

Repeat Steps 2 through 3.

Step 10: Repeat for additional Navigation Data Sources

Repeat Steps 1 through 9 for each Navigation Data Source input interface that the equipment is designed to accommodate.

2.4.3.2.4.8.3 Verification of Surface Longitude Position Extrapolation/Estimation (non - precision) (§2.2.3.2.4.8.3)

Appropriate test procedures are provided in §2.4.3.2.4.8.3.1 and §2.4.3.2.4.8.3.2.

2.4.3.2.4.8.3.1 Verification of Surface Longitude Position Extrapolation Case (non - precision) (§2.2.3.2.4.8.3.1)

The test procedures provided in §2.4.3.2.4.8.2.1 **shall** be used to validate performance of §2.4.3.2.4.8.3.1.

2.4.3.2.4.8.3.2 Verification of Surface Longitude Position Estimation Case (non - precision) (§2.2.3.2.4.8.3.2)

The test procedures provided in §2.4.3.2.4.8.2.2 **shall** be used to validate performance of §2.4.3.2.4.8.3.2.

2.4.3.2.4.8.4 Verification of Surface Longitude Position Data Retention (§2.2.3.2.4.8.4, §2.2.5.1.8)

Purpose/Introduction:

The extrapolation or estimation, and update of longitude data and fields specified in §2.2.3.2.4.8.2 through §2.2.3.2.4.8.3.2 **shall** be limited to no more than two seconds, in the event that the longitude position data is no longer available. At the end of two seconds, the longitude data registers and the encoded longitude field **shall** be set to ALL ZEROs.

Measurement Procedure:

Step 1: Longitude Data Termination - Part 1

Provide normal Surface Position data to the ADS-B Transmitting Subsystem at the nominal rate. First, filter the data so that the ADS-B Transmitting Subsystem does not receive any longitude data for at least 2 seconds. After 2 seconds, verify that the longitude data registers are set to ALL ZEROs.

Note: *In order to terminate longitude data, it may also be necessary to terminate latitude information since a position fix normally includes both latitude and longitude.*

Step 2: Longitude Data Termination - Part 2

For equipment that can independently filter latitude and longitude, return to providing normal Surface Position data at the nominal rate. Next, filter the data so that the device does not receive any longitude data. After 1 second, stop providing data. Verify that after 1 second more, the longitude registers are set to ALL ZEROs. Verify that after 1 second more, the longitude registers are set to ALL ZEROs.

2.4.3.2.5 Verification of ADS-B Aircraft Identification and Category Messages (§2.2.3.2.5)

The format for the Aircraft Identification and Category Message “ME” field contents is specified in Figure 2-6. Testing requirements for each of the subfields is specified in the following subparagraphs.

2.4.3.2.5.1 Verification of “TYPE” Subfield in ADS-B Aircraft Identification and Category Message (§2.2.3.2.5.1)

The test procedures provided in §2.4.3.2.5.2 **shall** be used to validate performance of §2.4.3.2.5.1.

2.4.3.2.5.2 Verification of "ADS-B Emitter Category" Subfield in ADS-B Aircraft Identification and Category Message (§2.2.3.2.5.2, §2.2.5.1.2)

Purpose/Introduction:

Each of the ADS-B Emitter Category Sets specified in Table 2-21. are used to identify particular aircraft or vehicle types within the ADS-B Emitter Category Sets A, B, C, or D identified by Message Format TYPE codes 4, 3, 2 and 1 respectively.

Measurement Procedure:

Step 1: Emitter Category Data Input

Provide the ADS-B Transmitting Subsystem with appropriate ADS-B Emitter Category data via the appropriate interface. Vary the "Emitter Category" data input through the range of codes, for appropriate values between 0 through 7 for Emitter Category Sets "A," "B," "C" and "D," for all Emitter Categories and codes that the system supports.

For each ADS-B Emitter Category data input selected, verify that the Format TYPE Code is properly transmitted in the ADS-B Aircraft Identification and Category Message.

For each ADS-B Emitter Category data input selected, verify that the ADS-B Emitter Category subfield is properly transmitted in the ADS-B Aircraft Identification and Category Message in accordance with the encodings provided in Table 2-21.

Step 2: Emitter Category Data Not Available

Set up the ADS-B Transmitting Subsystem as in Step 1 above. Discontinue the input of valid ADS-B Emitter Category data and verify that the ADS-B Emitter Category Subfield is set to ALL ZEROs (binary 000) in the Aircraft Identification and Category Message.

2.4.3.2.5.3 Verification of "Character" Subfield in ADS-B Aircraft Identification and Category Message (§2.2.3.2.5.3, §2.2.5.1.11)

Purpose/Introduction:

Each of the 8 "Character" subfields is a 6-bit field as shown in Figure 2-6.

Measurement Procedure:

Step 1: Aircraft Identification Data Input - Part 1

Provide the ADS-B Transmitting Subsystem with appropriate ADS-B Emitter Category data via the appropriate interface. Set the input data for each of the eight characters to the character "5."

Verify that each of the characters in the ADS-B Aircraft Identification and Category Message is transmitted properly in accordance with the encoding provided in §A.1.4.4.1 of Appendix A. For an input character of "5," the encoding for each character should be 110101 Binary.

Step 2: Aircraft Identification Data Input - Part 2

Provide the ADS-B Transmitting Subsystem with appropriate ADS-B Emitter Category data via the appropriate interface. Set the input data for each of the eight characters to the character "J."

Verify that each of the characters in the ADS-B Aircraft Identification and Category Message is transmitted properly in accordance with the encoding provided in §A.1.4.4.1 of Appendix A. For an input character of "J," the encoding for each character should be 001010 Binary.

Step 3: Aircraft Registration Marking Data Input

Repeat Step 1 and 2 while providing the ADS-B Transmitting Subsystem with Aircraft Registration Marking data instead of Aircraft Identification via the appropriate interface.

Step 4: No Aircraft Identification or Aircraft Registration Data

Discontinue the input of Aircraft Identification or Aircraft Registration Marking Data. Verify that each of the characters in the ADS-B Aircraft Identification and Category Message is transmitted properly with all bits of each character set to a binary ZERO (0). The encoding for each character should be ALL ZEROs (binary 000000).

Note: *The message will continue to be transmitted as long as Category data continues to be updated.*

2.4.3.2.6 Verification of ADS-B Airborne Velocity Messages (§2.2.3.2.6)

Formats for the various Airborne Velocity Messages are further classified by Subtype as identified in Figure 2-7 and Figure 2-8. Test procedures to verify the various fields within the Airborne Velocity Message are described in the following paragraphs.

2.4.3.2.6.1 Verification of ADS-B Airborne Velocity Message - Subtype=1 (§2.2.3.2.6.1)

Appropriate test procedures required to validate the correct transmission of the parameters of the ADS-B Airborne Velocity Message – Subtype=1 are provided in §2.4.3.2.6.1.1 through §2.4.3.2.6.1.15.

Purpose/Introduction:

Additionally, the requirement of §2.2.3.2.6.1.c states that: "this message **shall** not be broadcast if the only valid data is the Intent Change Flag."

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages. Set the ADS-B Transmitting Subsystem to Airborne Status. Provide valid input data and verify that Airborne Velocity Messages – Subtype=1 are being broadcast. Discontinue all of the input data to the data fields except for the Intent Change Flag data. Wait 2.6 seconds and verify that the Airborne Velocity Message – Subtype=1 is no longer being broadcast.

Repeat this procedure for Airborne Velocity Messages of Subtypes "2," "3" and "4."

2.4.3.2.6.1.1 Verification of "TYPE" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.1)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.1.2 Verification of "Subtype" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.1, §2.2.3.2.6.1.2, §2.2.3.2.6.2.1, §2.2.3.2.6.2.2, §2.2.3.2.6.3.1, §2.2.3.2.6.3.2, §2.2.3.2.6.4.1, §2.2.3.2.6.4.2, §2.2.3.2.7.1.1, §2.2.3.2.7.1.2, §2.2.3.2.7.2.1, §2.2.3.2.7.2.2)

Purpose/Introduction:

The "Subtype" subfield is contained in Message Bits 38 through 40 (ME Bits 6 through 8), and is encoded according to Figure 2-7. This test procedure is intended to verify that the appropriate Subtype subfield is used in all Airborne Velocity Messages.

Measurement Procedure:

Step 1: TYPE and Subtype Verification - Part 1

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide velocity information in the form of Velocity Over Ground (i.e., Ground Speed) with a valid value that is greater than zero but non-supersonic (i.e., both North/South AND East/West Velocity inputs are less than 1000 knots).

Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "1."

Raise the East/West Velocity input to a value of 1021 knots, and verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "1." Lower the East/West Velocity input to a value below 1000 knots, and raise the North/South Velocity input to a value of 1021 knots.

Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "1."

Lower the North/South Velocity input to a value below 1000 knots, then raise both the East/West and North/South Velocity inputs to values of 1021 knots.

Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "1."

Note: *During the execution of the previous step, care must be taken to ensure that neither the East/West nor the North/South Velocity inputs are raised to a value greater than 1021 knots.*

Step 2: TYPE and Subtype Verification - Part 2

This step verifies that the ADS-B Transmitting Subsystem correctly transitions between Subtype equal "1" and Subtype equal "2" in Airborne Velocity Messages.

Set up the system to enable broadcast of Airborne Velocity Messages as indicated in Step 1. Provide velocity information in the form of Velocity Over Ground (i.e., Ground Speed). Initially, both the East/West Velocity input and the North/South Velocity input **shall** be greater than 0 knots but less than 1000 knots, as in Step 1. Raise the East/West Velocity to a value of 1023 knots.

Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "2."

Decrease the East/West Velocity input to a value of 999 knots. Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages revert to Subtype value "1." Raise the North/South Velocity to a value of 1023 knots.

Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "2."

Decrease the North/South Velocity input to a value of 999 knots.

Verify that ADS-B Messages are generated with TYPE value "19" and that all such messages revert to Subtype value "1."

Raise both North/South and East/West input values to 1023 knots, and verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "2."

Decrease both North/South and East/West input values to 999 knots, and verify that ADS-B Messages are generated with TYPE value "19" and that all such messages contain Subtype value "1."

Step 3: TYPE and Subtype Verification - Part 3

Provide velocity information in the form of Airspeed and Heading Information with a valid value that is greater than zero but non-supersonic (i.e., the Airspeed input is less than 1000 knots).

Verify that ADS-B Airborne Velocity Messages are generated with TYPE value “19” and that all such messages contain Subtype value “3.”

Raise the Airspeed input to 1021 knots, without exceeding the value of 1022 knots in the process.

Verify that ADS-B Messages are generated with TYPE value “19” and that all such messages contain Subtype value “3.”

Step 4: TYPE and Subtype Verification - Part 4

This step verifies that the ADS-B Transmitting Subsystem correctly transitions between Subtype equal “3” and Subtype equal “4” in Airborne Velocity Messages containing Airspeed and Heading Information.

Set up the system to enable broadcast of Airborne Velocity Messages as indicated in Step 1 but with velocity information provided in the form of Airspeed and Heading Information rather than Velocity Over Ground. Initially, the Airspeed input **shall** be greater than 0 knots but less than 1000 knots, as in Step 1. Raise the input Airspeed to a value of 1023 knots.

Verify that ADS-B Messages are generated with TYPE value “19” and that all such messages contain Subtype value “4.”

Decrease the Airspeed input to a value of 999 knots.

Verify that ADS-B Messages are generated with TYPE value “19” and that all such messages revert to Subtype value “3.”

2.4.3.2.6.1.3 Verification of “Intent Change Flag” Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.3, §2.2.3.2.6.2.3, §2.2.3.2.6.3.3, §2.2.3.2.6.4.3, §2.2.5.1.18)

Purpose/Introduction:

This test procedure verifies that the “Intent Change Flag” subfield is used to indicate a change in intent as specified in Table 2-23, and transmitted in the Airborne Velocity Message Message.

Measurement Procedure:

Step 1: "Intent Change Flag" Subfield in Airborne Velocity Messages (All Subtypes), Mode-S Transponder Implementations - Setup (§2.2.3.2.6.1.3.a)

For Mode-S Transponder Implementations only, configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide data externally at the interface to the ADS-B system, via GICB Registers 40_{16} to 42_{16}, appropriate to each of the four Airborne Velocity Message Subtypes (see §2.2.3.2.6), and enable broadcasting of the Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status, and provide valid non-zero velocity data to the ADS-B Transmitting System.

Step 2: "Intent Change Flag" Subfield in Airborne Velocity Messages (All Subtypes), Mode-S Transponder Implementations (§2.2.3.2.6.1.3.a)

Change the data input to GICB Registers 40_{16} to 42_{16}, and verify that after 4 seconds, and for each of the four Airborne Velocity Message Subtypes, that the ADS-B Airborne Velocity Messages are generated with TYPE value "19," and with Message Bit 41, ME Bit 9 ("Intent Change Flag" subfield) set to ONE (1).

With no further change at the data input to GICB Registers 40_{16} to 42_{16}, verify that after 18 ±1 seconds following the last intent change, the Message Bit 41, ME Bit 9 ("Intent Change Flag" subfield) is reset to ZERO (0).

Step 3: "Intent Change Flag" Subfield in Airborne Velocity Messages (All Subtypes), Non-Transponder Implementations - Setup (§2.2.3.2.6.1.3.b)

For Non-Transponder Implementations only, repeat Steps 1 and 2.

Verify that for each of the four Airborne Velocity Message Subtypes, that the ADS-B Airborne Velocity Messages are generated with TYPE value "19," and with Message Bit 41, ME Bit 9 ("Intent Change Flag" subfield) always set to ZERO (0).

2.4.3.2.6.1.4 Verification of "Reserved Bit-A" Subfield in Airborne Velocity Messages – Subtype=1 (§2.2.3.2.6.1.4)

Purpose/Introduction:

The "Reserved Bits-A" subfield is a 1-bit ("ME" bit 10, Message bit 42) field that **shall** be set to ZERO (0) in all ADS-B Transmitting Subsystems that comply with these MOPS.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to broadcast Airborne Velocity Messages – Subtype=1 at the nominal rate. Verify that the "Reserved Bits-A" subfield is set to ZERO (0) in all transmitted messages.

2.4.3.2.6.1.5 Verification of "NAC_V" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.5, §2.2.3.2.6.2.5, §2.2.3.2.6.3.5, §2.2.3.2.6.4.5, §2.2.5.1.19)

Purpose/Introduction:

The "NAC_V" subfield is used to indicate the Navigation Accuracy Category for Velocity as specified in Table 2-25. These test procedures are intended for use for Airborne Velocity Messages of all Subtypes. The type and values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Note: *Subsequent to Revision A of the 1090 MHz ADS-B MOPS, the Federal Aviation Administration requested RTCA SC-159 to develop test procedures for a velocity accuracy test to characterize the 95% horizontal and 95% vertical velocity accuracies during normal maneuvers of GNSS equipment, as specified in RTCA/DO-229D, RTCA/DO-316, and RTCA/DO-253C receiver MOPS, which do not provide a specific velocity accuracy output. These tests can be used to substantiate Global Positioning System (GPS), GPS/Space-Based Augmentation System (SBAS), or GPS/Ground-Based Augmentation System (GBAS) equipment to support an ADS-B NAC_V =1 requirement of horizontal velocity error less than 10 meters/second (95th percentile with HDOP of 1.5 or less) and vertical velocity error less than 50 feet/second (95th percentile, with VDOP of 3.0 or less). Additional test procedures were developed to substantiate equipment that supports a NAC_V =2 requirement of horizontal velocity error less than 3 meters/second and vertical velocity error less than 15 feet/second. However, these tests are not adequate for demonstrating more stringent ADS-B NAC_V levels (i.e., NAC_V =3, or greater), but are expected to be developed as more demanding ADS-B applications mature. The results of these tests can be used to substantiate the setting of a NAC_V value to be used when ADS-B position and velocity are provided by the GPS equipment, presuming that that equipment does not have a specific velocity accuracy output.*

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero velocity data to the ADS-B System.

From an external source, input 95% accuracy figures of merit for horizontal velocity, and verify that for each horizontal velocity error value in Table 2-25 that the system generates Airborne Velocity Messages with the NAC_V subfield set equal to the corresponding binary coding value shown for the NAC_V subfield in Table 2-25.

2.4.3.2.6.1.6 Verification of "East/West Direction Bit" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.6, §2.2.3.2.6.2.6, §2.2.5.1.12)

Purpose/Introduction:

The "East/West Direction Bit" subfield is contained in Message Bit 46 (ME Bit 14) of Airborne Velocity Messages - Subtypes "1" and "2." This test procedure verifies that the "East/West Direction Bit" subfield in Airborne Velocity Messages is correctly set to ZERO (0) for inputs indicating travel in an eastward direction, and ONE (1) for travel in a westward direction.

These test procedures are intended for use for Airborne Velocity Messages of Subtypes "1" and "2." The values of the input Velocity data should be set so as to generate Airborne Velocity Messages for each Subtype value.

Measurement Procedure:

Step 1: East/West Direction Bit Verification when Velocity is Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages with Subtype=1 by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero velocity data to the ADS-B System.

Verify that when East/West Velocity Data is not provided to the ADS-B Transmitting Subsystem, the "East/West Direction Bit" subfield is set to ZERO (0).

Step 2: East/West Direction Bit Verification – Directional Components

The method for testing this field depends largely upon the nature of the input for East/West Velocity Data.

CASE 1:

If the directional component of the input is a single bit or a "flag" type (i.e. a single discrete value is used to represent "EAST," and another discrete value is used to represent "WEST"), then the procedure for this step **shall** be as follows.

Set the input to the value that indicates travel in an eastward direction, and check that ADS-B Airborne Velocity Messages are generated with TYPE value "19," and that all such messages contain an "East/West Direction Bit" subfield with a value of ZERO (0).

Next, set the input to the value that indicates travel in a westward direction. Verify that ADS-B Airborne Velocity Messages are generated with TYPE value "19," and that all such messages contain an "East/West Direction Bit" subfield with a value of ONE (1).

CASE 2:

If the directional component of the input is variable (e.g. a heading expressed in degrees or other similar manner so that the input value must be evaluated by the ADS-B Transmitting Subsystem in order to determine the proper value for the "East/West Direction Bit"), then the test procedure **shall** be as follows. In this case, the input variable must be made to assume values corresponding to movement in an eastward direction.

It must be verified for each such input value that Airborne Velocity Messages are generated with TYPE value "19" and that all such messages contain an "East/West Direction Bit" subfield with a value of ZERO (0).

The input must then be varied to assume values corresponding to movement in a westward direction. It must be verified for each such value that the system generates Airborne Velocity Messages with TYPE value "19" and that all such messages contain an "East/West Direction Bit" subfield with a value of ONE (1).

2.4.3.2.6.1.7 Verification of "East/West Velocity" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.7, §2.2.5.1.12)

Purpose/Introduction:

The "East/West Velocity" subfield is contained in Message Bits 47 through 56 (ME Bits 15 through 24) of Airborne Velocity Messages - Subtypes "1" and "2." The following test procedures verify that the "East/West Velocity" subfield in Airborne Velocity Messages is correctly set according to the coding specified.

Measurement Procedure:

Step 1: East/West Velocity Verification – Velocity Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages with Subtype=1 (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero velocity data to the ADS-B System. Discontinue East/West Velocity data.

Verify that when East/West Velocity Data is not provided to the ADS-B Transmitting Subsystem, the "East/West Velocity" subfield is set to ZERO (binary 00 0000 0000).

Step 2: East/West Velocity Verification – Velocity Equal ZERO

Setup the ADS-B Transmitting Subsystem as in Step 1 and set the East/West Velocity input to represent a velocity of ZERO knots. Verify that the East/West Velocity subfield is set to ONE (1) (binary 00 0000 0001).

Step 3: East/West Velocity Verification – Discrete Values

Verify that for each integer East/West Velocity input value in knots in Table 2-135, that the system generates Airborne Velocity Messages with the TYPE Subfield equal to "19" and that the "East/West Velocity" subfield in each such message is set equal to the corresponding binary coding value in Table 2-135.

Table 2-135: Discrete Values for East/West Velocity

East/West Velocity (subsonic)		
Coding		**Meaning**
(Binary)	(Decimal)	(E/W Velocity in knots)
00 0000 0010	2	E/W Velocity = 1 knot
00 0000 0101	5	E/W Velocity = 4 knots
00 0000 1010	10	E/W Velocity = 9 knots
00 0000 1111	15	E/W Velocity = 14 knots
00 0101 0000	80	E/W Velocity = 79 knots
00 0101 1010	90	E/W Velocity = 89 knots
00 1010 0101	165	E/W Velocity = 164 knots
00 1010 1010	170	E/W Velocity = 169 knots
01 0101 0101	341	E/W Velocity = 340 knots
10 0101 0101	597	E/W Velocity = 596 knots
10 1010 1010	682	E/W Velocity = 681 knots
11 0101 0101	853	E/W Velocity = 852 knots
11 1010 1010	938	E/W Velocity = 937 knots
11 1111 1110	1022	E/W Velocity = 1021 knots

Step 4: East/West Velocity Verification – Maximum Values

If the resolution of the input value is the same as the resolution of the "East/West Velocity" subfield in the output message (i.e., 1 knot), verify that for an input corresponding to an eastward velocity of 1022 (in knots), Airborne Velocity Messages are generated with TYPE "19" and all such messages contain an "East/West Velocity" subfield with a value of 1023 (binary 11 1111 1111).

If the resolution of the input value is greater than the resolution of the "East/West Velocity" subfield, verify that for the input value corresponding to the largest possible eastward velocity that is less than 1021.5 knots, Airborne Velocity Messages – Subtype=1 are generated and all such messages contain an "East/West Velocity" subfield with a value of 1022 (binary 11 1111 1110).

If the resolution of the input data makes it possible to enter an input value that corresponds to exactly 1021.5 knots, then this value **shall** be input and it **shall** be verified that the resultant "East/West Velocity" subfield output field is equal to either 1022 (binary 11 1111 1110, represents 1021 knots) or 1023 (binary 11 1111 1111, represents > 1021.5 knots).

Step 5: East/West Velocity Verification - Part 5

If the input data used to establish the "East/West Velocity" subfield has more resolution than that required by the "East/West Velocity" subfield (i.e., more than

10 bits), then this step **shall** be used to ensure that the accuracy of the data is maintained such that it is not worse than ±½ LSB, where the LSB is the least significant bit of the "East/West Velocity" subfield.

If the input data field that is used to determine the output value of the "East/West Velocity" subfield consists of 10 bits or less, proceed to Step 6.

Enter an input value corresponding to an eastward velocity of 1.5 knots.

Verify that the value of the "East/West Velocity" subfield in the output message is either "2" (binary 00 0000 0010, represents 1 knot) or "3" (binary 00 0000 0011, represents 2 knots).

If the input field used to establish the "East/West Velocity" subfield has exactly 11 bits, skip to step 6. Otherwise (indicating that more than 11 bits are used to establish "East/West Velocity" subfield), let *Z* be equal to the smallest possible fraction that can be represented by the number of bits in the input field (i.e., *Z* is the value of the least significant bit of the input field). Set the value of the input field to correspond to an eastward velocity of (1.5 – *Z*).

Verify that the value of the "East/West Velocity" subfield in the output Airborne Velocity Message is "2" (binary 00 0000 0010, represents 1 knot).

Set the value of the input field to correspond to an eastward velocity of (1.5 + *Z*).

Verify that the value of the "East/West Velocity" subfield in the output Airborne Velocity Message is "3" (binary 00 0000 0011, represents 2 knots).

Note: *If the resolution of the East/West Velocity input is such that an eastward velocity of 1.5 knots cannot be represented (but is still greater than 1 knot, e.g., a resolution of 0.2 knot increments), then values corresponding to eastward velocity must be tested, and the output examined for each value to confirm that the output is within ±0.5 knots (inclusive) of the input value.*

Step 6: East/West Velocity Verification - Part 6

Note: *If the nature of the inputs is such that a separate bit or "flag" type field is input to the transmitter to indicate "East" or "West," the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the "East/West Direction Bit," the following step must be performed.*

Repeat Steps 3, 4 and 5 so that each step is performed with East/West Velocity input data indicating travel in both EAST and WEST directions, i.e., replace the word "eastward" with "westward" in steps 3, 4 and 5.

2.4.3.2.6.1.8 Verification of "North/South Direction Bit" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.8, §2.2.3.2.6.2.8, §2.2.5.1.13)

Purpose/Introduction:

The "North/South Direction Bit" subfield is contained in Message Bit 57 (ME Bit 25) of Airborne Velocity Messages - Subtypes "1" and "2." This test procedure verifies that the "North/South Direction Bit" subfield in Airborne Velocity Messages is correctly set to ZERO (0) for travel in a northward direction, and ONE (1) for travel in a southward direction.

These test procedures are intended for use for Airborne Velocity Messages of Subtypes "1" and "2." The values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: North/South Direction Bit Verification – Velocity Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity data at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data and valid non-zero velocity data to the ADS-B System.

Verify that when North/South Velocity Data is not provided to the ADS-B Transmitting Subsystem, the "North/South Direction Bit" subfield is set to ZERO (0), as specified in §2.2.5.1.13, item (e).

Step 2: North/South Direction Bit Verification – Directional Components

The method for testing this field depends largely upon the nature of the input for North/South Velocity Data.

CASE 1:

If the directional component of the input is a single bit or a "flag" type (i.e. a single discrete value is used to represent "NORTH," and another discrete value is used to represent "SOUTH"), then the procedure for this step **shall** be as follows:

Set this input to the value that indicates travel in a northward direction, and check that ADS-B Airborne Velocity Messages are generated with TYPE value "19," and that all such messages contain a "North/South Direction Bit" subfield with a value of ZERO (0).

Next, set the input to the value that indicates travel in a southward direction, and verify that ADS-B Airborne Velocity Messages are generated with TYPE value "19," and that all such messages contain a "North/South Direction Bit" subfield with a value of ONE (1).

CASE 2:

If the directional component of the input is variable (e.g., a heading expressed in degrees or other similar manner, so that the input value must be evaluated by the ADS-B Transmitting Subsystem in order to determine the proper value for the "North/South Direction Bit" subfield), then the test procedure **shall** be as follows.

In this case, the input variable must be made to assume values corresponding to movement in a northward direction, and it must be verified, for each such value, that Airborne Velocity Messages are generated with TYPE value "19" and that all such messages contain a "North/South Direction Bit" subfield with a value of ZERO (0).

The input must then be made to assume values corresponding to movement in a southward direction, and it must be verified, for each such value, that the transmitter generates Airborne Velocity Messages with TYPE value "19," and that all such messages contain a "North/South Direction Bit" subfield with a value of ONE (1).

2.4.3.2.6.1.9 Verification of "North/South Velocity" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.9, §2.2.5.1.13)

Purpose/Introduction:

The "North/South Velocity" subfield is contained in Message Bits 55 through 65 (ME Bits 23 through 33) of Airborne Velocity Messages - Subtypes "1" and "2." This test procedure verifies that the "North/South Velocity" subfield in Airborne Velocity Messages is correctly set.

Measurement Procedure:

Step 1: North/South Velocity Verification – Velocity Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system.

Set up the system to enable broadcast of Airborne Velocity Messages with Subtype=1 (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero velocity data to the ADS-B System.

Discontinue North/South Velocity data and verify that when North/South Velocity Data is not provided to the ADS-B Transmitting Subsystem, the "North/South Velocity" subfield is set to ZERO (binary 00 0000 0000).

Step 2: North/South Velocity Verification – Velocity Equal ZERO

Set up the ADS-B Transmitting Subsystem as above and set the North/South Velocity input to represent a velocity of ZERO knots.

Verify that the North/South Velocity subfield is set to ONE (1).

Step 3: North/South Velocity Verification – Discrete Values

Verify that for each integer North/South Velocity input value in knots in Table 2-136 that the system generates Airborne Velocity Messages with the TYPE Subfield equal to "19" and that the "North/South Velocity" subfield in each such message is set equal to the corresponding binary coding value in Table 2-136.

Table 2-136: Discrete Values for North/South Velocity

North/South Velocity (subsonic)		
Coding		**Meaning**
(Binary)	(Decimal)	(N/S Velocity in knots)
00 0000 0010	2	N/S Velocity = 1 knot
00 0000 0101	5	N/S Velocity = 4 knots
00 0000 1010	10	N/S Velocity = 9 knots
00 0000 1111	15	N/S Velocity = 14 knots
00 0101 0000	80	N/S Velocity = 79 knots
00 0101 1010	90	N/S Velocity = 89 knots
00 1010 0101	165	N/S Velocity = 164 knots
00 1010 1010	170	N/S Velocity = 169 knots
01 0101 0101	341	N/S Velocity = 340 knots
10 0101 0101	597	N/S Velocity = 596 knots
10 1010 1010	682	N/S Velocity = 681 knots
11 0101 0101	853	N/S Velocity = 852 knots
11 1010 1010	938	N/S Velocity = 937 knots
11 1111 1110	1022	N/S Velocity = 1021 knots

Step 4: North/South Velocity Verification – Maximum Values

If the resolution of the input value is the same as the output resolution (i.e., 1 knot), verify that for an input corresponding to a northward velocity of 1022 (in knots), Airborne Velocity Messages are generated with TYPE "19" and all such messages contain a "North/South Velocity" subfield with a value of 1023 (binary 11 1111 1111).

If the resolution of the input value is greater than the output resolution, verify that for input value corresponding to the largest possible northward velocity that is less than 1021.5 knots, Airborne Velocity Messages – Subtype=1 are generated and all such messages contain a "North/South Velocity" subfield with a value of 1022 (binary 11 1111 1110).

If the resolution of the input data makes it possible to enter an input value that corresponds to exactly 1021.5 knots, then this value **shall** be input and it **shall** be verified that the resultant "North/South Velocity" output field is equal to either 1022 (binary 11 1111 1110, representing 1021 knots) or 1023 (binary 11 1111 1111, representing > 1021.5 knots).

Step 5: North/South Velocity Verification - Part 5

If the input data used to establish the "North/South Velocity" subfield has more resolution than that required by the "North/South Velocity" subfield (i.e., more than 10 bits), then this step **shall** be used to ensure that the accuracy of the data is maintained such that it is not worse than ±½ LSB, where the LSB is the least significant bit of the "North/South Velocity" subfield. If the input data field that is used to determine the output value of the "North/South Velocity" subfield consists of 10 bits or less, proceed to Step 6.

Enter an input value corresponding to a northward velocity of 1.5 knots.

Verify that the value of the "North/South Velocity" subfield in the output message is either "2" (binary 00 0000 0010, representing 1 knot) or "3" (binary 00 0000 0011, representing 2 knots).

If the input field used to establish the "North/South Velocity" subfield has exactly 11 bits, skip to step 6. Otherwise (indicating that more than 11 bits are used to establish "North/South Velocity" subfield), let Z be equal to the smallest possible fraction that can be represented by the number of bits in the input field (i.e., Z is the value of the least significant bit of the input field). Set the value of the input field to correspond to a northward velocity of $(1.5 – Z)$.

Verify that the value of the "North/South Velocity" subfield in the output Airborne Velocity Message is "2" (binary 00 0000 0010, representing 1 knot).

Set the value of the input field to correspond to a northward velocity of $(1.5 + Z)$.

Verify that the value of the "North/South Velocity" subfield in the output Airborne Velocity Message is "3" (binary 00 0000 0011, representing 2 knots).

Note: *If the resolution of the North/South Velocity input is such that a northward velocity of 1.5 knots cannot be represented (but is still greater than 1 knot, e.g., a resolution of 0.2 knot increments), then values corresponding to northward velocity must be tested, and the output examined for each value to confirm that the output is within ±0.5 knots (inclusive) of the input value.*

Step 6: North/South Velocity Verification - Part 6

Note: *If the nature of the inputs is such that a separate bit or "flag" type field is input to the transmitter to indicate "North" or "South," the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the "North/South Direction Bit," the following step must be performed.*

Repeat Steps 3, 4 and 5 so that each step is performed with North/South Velocity input data indicating travel in both NORTH and SOUTH directions, i.e., replace the word "northward" with "southward" in steps 3, 4 and 5.

2.4.3.2.6.1.10 Verification of "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.10, §2.2.3.2.6.2.10, §2.2.3.2.6.3.10, §2.2.3.2.6.4.10, §2.2.5.1.14)

Purpose/Introduction:

The "Source Bit for Vertical Rate" subfield is contained in Message Bit 68 (ME Bit 36) of Airborne Velocity Messages. The following test verifies that this bit is correctly set according to the table contained in the above referenced section.

These test procedures are intended for use for Airborne Velocity Messages of all subtypes. The type and values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: Vertical Rate Source Bit Verification - Part 1

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Information Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data and valid non-zero velocity data to the ADS-B System.

Verify that if the input Vertical Rate data is from Geometric Source (GNSS or INS), then the "Source Bit for Vertical Rate" subfield is set to ZERO (0).

Step 2: Vertical Rate Source Bit Verification - Part 2

Change the Vertical Rate input data so that it indicates to the ADS-B Transmitting Subsystem that it is from Barometric Source.

Verify that the "Source Bit for Vertical Rate" subfield in subsequent output messages is set to ONE (1).

2.4.3.2.6.1.11 Verification of "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.11, §2.2.3.2.6.2.11, §2.2.3.2.6.3.11, §2.2.3.2.6.4.11, §2.2.5.1.14)

Purpose/Introduction:

The "Sign Bit for Vertical Rate" subfield is contained in Message Bit 69 (ME Bit 37) of Airborne Velocity Messages. The following test verifies that this bit is correctly set to ZERO (0) to indicate an upward vertical rate vector (climb), and ONE (1) to indicate a downward vertical rate vector (descent).

These test procedures are intended for use for Airborne Velocity Messages of all Subtypes. The type and values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: "Sign Bit for Vertical Rate" Verification – Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data and valid non-zero velocity data to the ADS-B System.

Verify that when Vertical Rate Data is not provided to the ADS-B Transmitting Subsystem, the "Sign Bit for Vertical Rate" subfield is set to ZERO (0), as specified in §2.2.5.1.14, item (d).

Step 2: "Sign Bit for Vertical Rate" Directional Component Verification

The method for testing this field depends largely upon the nature of the input for "Vertical Rate" subfield Data.

CASE 1:

If the directional component of the input is a single bit or a "flag" type (i.e. a single discrete value is used to represent "UP," and another discrete value is used to represent "DOWN"), then the procedure for this step **shall** be as follows:

Set this input to the value that indicates an upward direction, and verify that ADS-B Airborne Velocity Messages are generated with TYPE value "19," and that all such messages contain a "Sign Bit for Vertical Rate" subfield with a value of ZERO (0).

Next, set the input to the value that indicates a downward direction, and verify that ADS-B Airborne Velocity Messages are generated with TYPE value "19," and that all such messages contain a "Sign Bit for Vertical Rate" subfield with a value of ONE (1).

CASE 2:

If the directional component of the input is variable (e.g., a heading expressed in degrees or other similar manner, so that the input value must be evaluated by the ADS-B Transmitting Subsystem in order to determine the proper value for the "Sign Bit for Vertical Rate" subfield), then the test procedure **shall** be as follows.

In this case, the input variable must be made to assume values corresponding to an upward climb, and it must be verified, for each such value, that Airborne Velocity Messages are generated with TYPE value "19" and that all such messages contain a "Sign Bit for Vertical Rate" subfield with a value of ZERO (0).

The input must then be made to assume values corresponding to a descent, and it must be verified, for each such value, that the transmitter generates Airborne

Velocity Messages with TYPE value "19," and that all such messages contain a "Sign Bit for Vertical Rate" subfield with a value of ONE (1).

2.4.3.2.6.1.12 Verification of "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.12, §2.2.3.2.6.2.12, §2.2.3.2.6.3.12, §2.2.3.2.6.4.12, §2.2.5.1.14)

Purpose/Introduction:

The "Vertical Rate" subfield is contained in Message Bits 70 through 78 (ME Bits 38 through 46) of Airborne Velocity Messages. This test procedure verifies that the "Vertical Rate" subfield in Airborne Velocity Messages is correctly set.

These test procedures are intended for use for Airborne Velocity Messages of all Subtypes. The type and values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: "Vertical Rate" Not Available Verification

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data and valid non-zero velocity data to the ADS-B System.

Verify that when Vertical Rate Data is not provided to the ADS-B Transmitting Subsystem, the "Vertical Rate" subfield in Airborne Velocity output messages is set to ZERO (0) (binary 0 0000 0000).

Step 2: "Vertical Rate" Equal To ZERO Verification

The input for this field **shall** initially be set to represent a "Vertical Rate" of ZERO feet per minute.

Verify that the ADS-B Transmitting Subsystem generates Airborne Velocity Messages with TYPE "19" and that the "Vertical Rate" subfield in each such message contains the value ONE (1) (binary 0 0000 0001).

Step 3: "Vertical Rate" Verification – Discrete Values

Increase the value of the "Vertical Rate" Data input so that it assumes each discrete decimal coding value from Table 2-137.

Verify that for each discrete decimal coding input value, the "Vertical Rate" subfield in subsequent Airborne Velocity Messages of TYPE "19" matches identically the corresponding Binary Coding value from Table 2-137.

Table 2-137: Vertical Rate Discrete Values

Vertical Rate		
Coding		Meaning
(Binary)	(Decimal)	(Vertical Rate in feet / minute)
0 0000 0101	5	Vertical Rate = 256 feet / minute
0 0000 1010	10	Vertical Rate = 576 feet / minute
0 0000 1111	15	Vertical Rate = 896 feet / minute
0 0101 0000	80	Vertical Rate = 5,056 feet / minute
0 0101 1111	95	Vertical Rate = 6,016 feet / minute
0 1010 0000	160	Vertical Rate = 10,176 feet / minute
0 1010 1111	175	Vertical Rate = 11,136 feet / minute
0 1111 1111	255	Vertical Rate = 16,256 feet / minute
1 0000 0000	256	Vertical Rate = 16,320 feet / minute
1 0101 0101	341	Vertical Rate = 21,760 feet / minute
1 1010 1010	426	Vertical Rate = 27,200 feet / minute
1 1111 1110	510	Vertical Rate = 32,576 feet / minute

Verify that the “Vertical Rate” subfield in the output message is not incremented until the input value reaches a number corresponding to an integer multiple of 64 feet/minute with an accuracy of ±32 feet/minute.

Step 4: Vertical Rate Verification – Out of Bounds Test

Continue to increase the value of the Vertical Rate Data input.

Verify that for values greater than 32,576 feet per minute but less than or equal to 32,608 feet per minute, the “Vertical Rate” subfield continues to be set to “510” (binary 1 1111 1110).

Continue to increase the value of the vertical rate input.

Verify that for values representing a vertical rate greater than 32,608 feet per minute, up to the maximum possible input value, that the transmitter continues to generate Airborne Velocity Messages with a TYPE subfield equal to “19” and that the “Vertical Rate” subfield for all such messages is set to “511” (binary 1 1111 1111).

Step 5: Vertical Rate Verification - Part 5

Note: *If the nature of the inputs is such that a separate bit or “flag” type field is input to the transmitter to indicate “Up” or “Down,” the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the “Sign Bit for Vertical Rate” subfield, the following step must be performed.*

Repeat steps 3 through 5, so that each step is performed with “Vertical Rate” input data indicating directional vectors of both UP (climb) and DOWN (descent) turns.

2.4.3.2.6.1.13 Verification of "Reserved Bits-B" Subfield in Airborne Velocity Messages – Subtype=1 (§2.2.3.2.6.1.13)

Purpose/Introduction:

The "Reserved Bits-B" subfield is a 2-bit ("ME" bits 47 – 48, Message bits 79 – 80) field that **shall** be set to ZERO (binary 00) in all ADS-B Transmitting Subsystems that comply with these MOPS.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to broadcast Airborne Velocity Messages – Subtype=1 at the nominal rate. Verify that the "Reserved Bits-B" subfield is set to ZERO (binary 00) in all transmitted messages.

2.4.3.2.6.1.14 Verification of "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.14, §2.2.3.2.6.2.14, §2.2.3.2.6.3.14, §2.2.3.2.6.4.14)

Purpose/Introduction:

The "Difference From Barometric Altitude Sign Bit" is used to indicate the direction of the GNSS Altitude Source data as shown in Table 2-35. These test procedures are intended for use for Airborne Velocity Messages of all Subtypes. The type and values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: Difference from Baro Altitude Sign Bit Verification - Part 1

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Information Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data, valid non-zero Geometric Source data and valid non-zero velocity data to the ADS-B System. Set the inputs so that the input Geometric Altitude Source data is greater than (above) the input Barometric Altitude.

Verify that the "Difference From Barometric Altitude Sign Bit" subfield in subsequent Airborne Velocity output messages is set to ZERO (0).

Step 2: Difference from Baro Altitude Sign Bit Verification - Part 2

Lower the input Geometric Altitude Source data.

Verify that as long as the input Geometric Altitude Source data is greater than the input Barometric Altitude (in feet), all transmitted Airborne Velocity Messages continue to contain a ZERO (0) in the SIGN BIT subfield.

Verify that as soon as the input Geometric Altitude Source data becomes lower than the input Barometric Altitude, the SIGN BIT subfield in Airborne Velocity Messages is changed to a ONE (1).

2.4.3.2.6.1.15 Verification of "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=1 (§2.2.3.2.6.1.15, §2.2.3.2.6.2.15, §2.2.3.2.6.3.15, §2.2.3.2.6.4.15)

Purpose/Introduction:

The "Difference From Barometric Altitude" subfield is used to report the difference between Geometric (GNSS or INS) Altitude Source data and Barometric Altitude when both types of Altitude Data are available and valid, and is encoded as shown in Table 2-36. These test procedures are intended for use for Airborne Velocity Messages of all Subtypes. The type and values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: Difference from Barometric Altitude Verification – Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Information Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data, valid non-zero Geometric Altitude Source data and valid non-zero velocity data to the ADS-B System.

Discontinue the input of Geometric Altitude Source data and verify that subsequent Airborne Velocity Messages contain a "Difference From Barometric Altitude" subfield with a value of ZERO (0) (binary 000 0000). Stop the input of Barometric Altitude data and verify that the value of this field remains ZERO (0) in subsequent Airborne Velocity Messages.

Begin the input of only Geometric Altitude Source data and verify that the value of this field remains ZERO (0) in subsequent messages of this type.

Step 2: Difference from Barometric Altitude Verification – No Differences

Re-start the input of Barometric Altitude data, and set the inputs so that the Geometric Altitude Source data input and the Barometric Altitude input both represent the exact same altitude (in feet); i.e., the difference between the two altitude values is ZERO.

Verify that the "Difference From Barometric Altitude" subfield in subsequent Airborne Velocity Messages is set to ONE (1) (binary 000 0001, representing a Difference of ZERO).

Step 3: Difference from Barometric Altitude Verification – Discrete Values

Adjust the value of the Barometric Altitude input data so that the set of possible inputs includes a value that represents an altitude at least 3,140 feet above the chosen value and a value that represents an altitude at least 3,140 feet below the chosen value. Adjust the Geometric Altitude Source data input to represent the same altitude as that chosen for the Barometric Altitude input.

Increase the value of the Geometric Altitude Source data input while keeping the Barometric Altitude constant so that the Geometric Altitude Source data difference input assumes each value from Table 2-138. Verify that for each Altitude Source Data Difference in Table 2-138 that the system generates Airborne Velocity Messages with the "Difference From Barometric Altitude" subfield in each message set equal to the corresponding binary coding value from the table.

Table 2-138: Difference from Barometric Altitude Discrete Values

Difference From Barometric Altitude		
Coding		**Meaning**
(Binary)	(Decimal)	(Geometric (GNSS or INS) Altitude Source data Difference in feet)
000 0010	2	GNSS Altitude Source data Difference = 25 feet
000 0011	3	GNSS Altitude Source data Difference = 50 feet
000 0101	5	GNSS Altitude Source data Difference = 100 feet
000 1010	10	GNSS Altitude Source data Difference = 225 feet
001 0101	21	GNSS Altitude Source data Difference = 500 feet
010 1010	42	GNSS Altitude Source data Difference = 1025 feet
101 0101	85	GNSS Altitude Source data Difference = 2100 feet
101 1010	90	GNSS Altitude Source data Difference = 2225 feet
111 1110	126	GNSS Altitude Source data Difference = 3125 feet

Additionally verify that for every 25 feet increase in the difference between the two, the "Difference From Barometric Altitude" subfield in subsequent Airborne Velocity Messages of TYPE "19" is incremented by one from the previous value (i.e., that the value of the "Difference From Barometric Altitude" subfield corresponds to the decimal coding values given in the table in the above referenced section).

Verify that the "Difference From Barometric Altitude" subfield in the output message is not incremented until the difference in the input values reaches a number corresponding to an integer multiple of 25 feet with an accuracy of ±12.5 feet.

Step 4: Difference from Barometric Altitude Verification - Part 4

Continue to increase the value of the Geometric Altitude Source Data input.

Verify that, for values that are greater than 3,125 feet above the Barometric Altitude, but less than or equal to 3,137.5 feet above the Barometric Altitude, the "Difference From Barometric Altitude" subfield continues to be set to "126" (binary 111 1110).

Continue to increase the value of the Geometric Altitude Source data input.

Verify, for values representing an altitude greater than 3,137.5 feet above the barometric altitude, up to the maximum possible input value, that the transmitter continues to generate Airborne Velocity Messages and that the "Difference From Barometric Altitude" subfield for all such messages is set to "127" (binary 111 1111).

Step 5: Difference from Barometric Altitude Verification - Part 5

Note: *If the nature of the inputs is such that a separate bit or "flag" type field is input to the transmitter to indicate "Up" or "Down," the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the "Difference From Barometric Altitude Sign Bit," the following step must be performed.*

Repeat steps 3 through 5, but this time decreasing the value of the Geometric Altitude Source data input, rather than increasing it.

2.4.3.2.6.2 Verification of ADS-B Airborne Velocity Message - Subtype=2 (§2.2.3.2.6.2)

Appropriate test procedures are provided in §2.4.3.2.6.2.1 through §2.4.3.2.6.2.15.

2.4.3.2.6.2.1 Verification of "TYPE" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.1)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.2.2 Verification of "Subtype" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.2)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.2.3 Verification of "Intent Change Flag" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.3, §2.2.5.1.18)

Appropriate test procedures are provided in §2.4.3.2.6.1.3.

2.4.3.2.6.2.4 Verification of "Reserved Bit-A" Subfield in Airborne Velocity Messages – Subtype=2 (§2.2.3.2.6.2.4)

Appropriate test procedures are provided in §2.4.3.2.6.1.4.

2.4.3.2.6.2.5 Verification of "NAC_V" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.5, §2.2.5.1.19)

Appropriate test procedures are provided in §2.4.3.2.6.1.5.

2.4.3.2.6.2.6 Verification of "East/West Direction Bit" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.6)

Appropriate test procedures are provided in §2.4.3.2.6.1.6.

2.4.3.2.6.2.7 Verification of "East/West Velocity" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.7, §2.2.5.1.12)

Purpose/Introduction:

The following test procedures verify that the "East/West Velocity" subfield in Airborne Velocity Messages is correctly set according to the coding specified.

Measurement Procedure:

Step 1: East/West Velocity Verification – Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages with Subtype="2" (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate") by providing East/West Velocity input data with a value greater than 1022 knots. Set the ADS-B Transmitting Subsystem to Airborne status.

Discontinue East/West Velocity data and verify that when East/West Velocity Data is not provided to the ADS-B Transmitting Subsystem, the "East/West Velocity" Subfield in output Airborne Velocity Messages – Subtype=2 is set to ZERO (binary 00 0000 0000).

Step 2: East/West Velocity Verification – Velocity Equal ZERO

Set up the ADS-B Transmitting Subsystem as above and set the East/West Velocity input to represent a velocity of ZERO knots. Verify that the "East/West Velocity" Subfield in subsequent Airborne Velocity Messages – Subtype=2 is set to ONE (1) (binary 00 0000 0001).

Step 3: East/West Velocity Verification – Discrete Values

Verify that for each integer East/West Velocity input value in knots identified in Table 2-139 that the system generates Airborne Velocity Messages with the "East/West Velocity" Subfield set equal to the corresponding binary coding value in the table.

Table 2-139: East/West Velocity Discrete Values

East/West Velocity (supersonic)		
Coding		**Meaning**
(Binary)	(Decimal)	(E/W Velocity in knots)
00 0000 0010	2	E/W Velocity = 4 knots
00 0000 0101	5	E/W Velocity = 16 knots
00 0000 1010	10	E/W Velocity = 36 knots
00 0000 1111	15	E/W Velocity = 56 knots
00 0101 0000	80	E/W Velocity = 316 knots
00 0101 1010	90	E/W Velocity = 356 knots
00 1010 0101	165	E/W Velocity = 656 knots
00 1010 1010	170	E/W Velocity = 676 knots
01 0101 0101	341	E/W Velocity = 1,360 knots
10 0101 0101	597	E/W Velocity = 2,384 knots
10 1010 1010	682	E/W Velocity = 2,724 knots
11 0101 0101	853	E/W Velocity = 3,408 knots
11 1010 1010	938	E/W Velocity = 3,748 knots
11 1111 1110	1022	E/W Velocity = 4,084 knots

Verify that for 4 knot increases in the input value, the "East/West Velocity" subfield in subsequent Airborne Velocity Messages of TYPE "19" is incremented by one from the previous value (i.e., that the value of the "East/West Velocity" subfield binary values corresponds to the values given in the table in the above referenced section).

Verify that the "East/West Velocity" subfield in the output message is not incremented to the next higher integer value until the input velocity value reaches a number corresponding to an even multiple of 4 knots.

Step 4: East/West Velocity Verification – Maximum Velocity

Continue to increase the value of the East/West Velocity Data input.

Verify that, for values greater than or equal to 4084 knots but less than or equal to 4086 knots, the output "East/West Velocity" subfield continues to be set to "1022" (binary 11 1111 1110).

Continue to increase the value of the East/West Velocity input.

Verify, for every input value representing an East/West Velocity greater than 4086 knots, up to the maximum possible input value, that the transmitter continues to generate Airborne Velocity Messages with a TYPE subfield equal to "19," a

Subtype subfield equal to "2," and that the "East/West Velocity" subfield for all such messages is set to "1023" (binary 11 1111 1111).

Step 5: East/West Velocity Verification – Input Resolution

If the input data used to establish the "East/West Velocity" subfield has more resolution than that required by the "East/West Velocity" subfield, then this step **shall** be used to ensure that the accuracy of the data is maintained such that it is not worse than ±½ LSB, where the LSB is the least significant bit of the "East/West Velocity" subfield. If the input data field that is used to determine the output value of the "East/West Velocity" subfield does not have finer resolution than that required by the "East/West Velocity" subfield, proceed to Step 6.

Enter an input value corresponding to an eastward velocity of 6 knots.

Verify that the value of the "East/West Velocity" subfield in the output message is either "2" (binary 00 0000 0010, representing 4 knots) or "3" (binary 00 0000 0011, representing 8 knots).

If the input field used to establish the "East/West Velocity" subfield does not have resolution finer than 2 knots, skip to step 6. Otherwise (indicating that East/West Velocity input resolution is finer than 2 knots), let Z be equal to the smallest possible value that can be represented by the number of bits in the input field (i.e., Z is the value of the least significant bit of the input field).

Set the value of the input field to correspond to an eastward velocity of $(6 - Z)$.

Verify that the value of the "East/West Velocity" subfield in the output Airborne Velocity Message is "2" (binary 00 0000 0010, representing 4 knots).

Set the value of the input field to correspond to an eastward velocity of $(6 + Z)$.

Verify that the value of the "East/West Velocity" subfield in the output Airborne Velocity Message is "3" (binary 00 0000 0011, representing 8 knots).

Note: *If the resolution of the East/West Velocity input is such that an eastward velocity of 6 knots cannot be represented (but is still finer than 4 knots, e.g., a resolution of 1.75 knot increments), then values corresponding to eastward velocity must be tested, and the output examined for each value to confirm that the output is within ±2 knots (inclusive) of the input value.*

Step 6: East/West Velocity Verification - Part 6

Note: *If the nature of the inputs is such that a separate bit or "flag" type field is input to the transmitter to indicate "East" or "West," the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the "East/West Direction Bit," the following step must be performed.*

Repeat Steps 3, 4 and 5 so that each step is performed with East/West Velocity input data indicating travel in both EAST and WEST directions, i.e., replace the word "eastward" with "westward" in steps 3, 4 and 5.

2.4.3.2.6.2.8 Verification of "North/South Direction Bit" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.8)

Appropriate test procedures are provided in §2.4.3.2.6.1.8.

2.4.3.2.6.2.9 Verification of "North/South Velocity" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.9, §2.2.5.1.13)

Purpose/Introduction:

This test procedure verifies that the "North/South Velocity" subfield in Airborne Velocity Messages is correctly set.

Measurement Procedure:

Step 1: North/South Velocity Verification – Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages with Subtype=2 (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate") by providing North/South Velocity input data with a value greater than 1022 knots.

Set the ADS-B Transmitting Subsystem to Airborne status. Discontinue North/South Velocity data and verify that when North/South Velocity Data is not provided to the ADS-B Transmitting Subsystem, the "North/South Velocity" subfield in output Airborne Velocity Messages – Subtype=2 is set to ZERO (binary 00 0000 0000).

Step 2: North/South Velocity Verification – Velocity Equal ZERO

Setup the ADS-B Transmitting Subsystem as above and set the North/South Velocity input to represent a velocity of ZERO knots. Verify that the "North/South Velocity" subfield in subsequent Airborne Velocity Messages – Subtype=2 is set to ONE (1) (binary 00 0000 0001).

Step 3: North/South Velocity Verification – Discrete Values

Verify that for each integer North/South Velocity input value in knots identified in Table 2-140 that the system generates Airborne Velocity Messages with the "North/South Velocity" subfield set equal to the corresponding binary coding value in the table.

Table 2-140: North/South Velocity Discrete Values

North/South Velocity (supersonic)		
Coding		**Meaning**
(Bianry)	(Decimal)	(N/S Velocity in knots)
00 0000 0010	2	N/S Velocity = 4 knots
00 0000 0101	5	N/S Velocity = 16 knots
00 0000 1010	10	N/S Velocity = 36 knots
00 0000 1111	15	N/S Velocity = 56 knots
00 0101 0000	80	N/S Velocity = 316 knots
00 0101 1010	90	N/S Velocity = 356 knots
00 1010 0101	165	N/S Velocity = 656 knots
00 1010 1010	170	N/S Velocity = 676 knots
01 0101 0101	341	N/S Velocity = 1,360 knots
10 0101 0101	597	N/S Velocity = 2,384 knots
10 1010 1010	682	N/S Velocity = 2,724 knots
11 0101 0101	853	N/S Velocity = 3,408 knots
11 1010 1010	938	N/S Velocity = 3,748 knots
11 1111 1110	1022	N/S Velocity = 4,084 knots

Verify that for 4 knot increases in the input value, the "North/South Velocity" subfield in subsequent Airborne Velocity Messages of TYPE "19" is incremented by one from the previous value (i.e., that the value of the "North/South Velocity" subfield corresponds to the values given in the table in the above referenced section).

Verify that the "North/South Velocity" subfield in the output message is not incremented until the input value reaches a number corresponding to an even multiple of 4 knots.

Step 4: North/South Velocity Verification – Maximum Velocity

Continue to increase the value of the North/South Velocity Data input.

Verify that, for discrete values greater than or equal to 4084 knots but less than or equal to 4086 knots, the "North/South Velocity" subfield continues to be set to "1022" (binary 11 1111 1110).

Continue to increase the value of the North/South Velocity input.

Verify that for discrete input values representing a North/South Velocity greater than 4086 knots, up to the maximum possible input value, that the transmitter continues to generate Airborne Velocity Messages with a TYPE subfield equal to "19," a Subtype subfield equal to "2," and that the "North/South Velocity" subfield for all such messages is set to "1023" (binary 11 1111 1111).

Step 5: North/South Velocity Verification – Input Resolution

If the input data used to establish the "North/South Velocity" subfield has finer resolution than that required by the "North/South Velocity" subfield, then this step **shall** be used to ensure that the accuracy of the data is maintained such that it is not worse than ±½ LSB, where the LSB is the least significant bit of the “North/South Velocity” subfield. If the input data field that is used to determine the output value of the “North/South Velocity” subfield does not have finer resolution than that required by the “North/South Velocity” subfield, proceed to Step 6.

Enter an input value corresponding to a northward velocity of 6 knots.

Verify that the value of the “North/South Velocity” subfield in the output message is either “2” (binary 00 0000 0010, representing 4 knots) or “3” (binary 00 0000 0011, representing 8 knots).

If the input field used to establish the “North/South Velocity” subfield does not have resolution finer than 2 knots, skip to step 6. Otherwise (North/South Velocity input resolution is finer than 2 knots), let *Z* be equal to the smallest possible value that can be represented by the number of bits in the input field (i.e., *Z* is the value of the least significant bit of the input field). Set the value of the input field to correspond to a northward velocity of (6 – *Z*).

Verify that the value of the “North/South Velocity” subfield in the output Airborne Velocity Message is “2” (binary 00 0000 0010, representing 4 knots). Set the value of the input field to correspond to a northward velocity of (6 + *Z*).

Verify that the value of the “North/South Velocity” subfield in the output Airborne Velocity Message is “3” (binary 00 0000 0011, representing 8 knots).

Note: *If the resolution of the North/South Velocity input is such that a northward velocity of 6 knots cannot be represented (but is still finer than 4 knots, e.g., a resolution of 1.75 knot increments), then values corresponding to northward velocity must be tested, and the output examined for each value to confirm that the output is within ±2 knots (inclusive) of the input value.*

Step 6: North/South Velocity Verification - Part 6

Note: *If the nature of the inputs is such that a separate bit or “flag” type field is input to the transmitter to indicate “North” or “South,” the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the “North/South Direction Bit,” the following step must be performed.*

Repeat Steps 3, 4 and 5 so that each step is performed with North/South Velocity input data indicating travel in both NORTH and SOUTH directions, i.e., replace the word “northward” with “southward” in steps 3, 4 and 5.

2.4.3.2.6.2.10 Verification of “Source Bit for Vertical Rate” Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.10, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.10.

2.4.3.2.6.2.11 Verification of "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.11, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.11.

2.4.3.2.6.2.12 Verification of "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.12, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.12.

2.4.3.2.6.2.13 Verification of "Reserved Bits-B" Subfield in Airborne Velocity – Subtype=2 Messages (§2.2.3.2.6.2.13)

Appropriate test procedures are provided in §2.4.3.2.6.1.13.

2.4.3.2.6.2.14 Verification of "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.14.

2.4.3.2.6.2.15 Verification of "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=2 (§2.2.3.2.6.2.15)

Appropriate test procedures are provided in §2.4.3.2.6.1.15.

2.4.3.2.6.3 Verification of ADS-B Airborne Velocity Message - Subtype=3 (§2.2.3.2.6.3)

Appropriate test procedures are provided in §2.4.3.2.6.3.1 through §2.4.3.2.6.3.15.

2.4.3.2.6.3.1 Verification of "TYPE" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.1)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.3.2 Verification of "Subtype" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.1, §2.2.3.2.6.3.2)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.3.3 Verification of "Intent Change Flag" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.3, §2.2.5.1.18)

Appropriate test procedures are provided in §2.4.3.2.6.1.3.

2.4.3.2.6.3.4 Verification of "Reserved Bit-A" Subfield in Airborne Velocity Messages – Subtype=3 (§2.2.3.2.6.3.4)

Appropriate test procedures are provided in §2.4.3.2.6.1.4.

2.4.3.2.6.3.5 Verification of "NAC_V" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.5, §2.2.5.1.19)

Appropriate test procedures are provided in §2.4.3.2.6.1.5.

2.4.3.2.6.3.6 Verification of "Heading Status Bit" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.6, §2.2.3.2.6.4.6, §2.2.5.1.15)

Purpose/Introduction:

This test procedure verifies that the ADS-B Transmitting Subsystem correctly outputs Airborne Velocity Messages – Subtypes "3" and "4," with the "Heading Status Bit" correctly set to ONE (1) if Heading information is available, and ZERO (0) if it is not.

These test procedures are intended for use for Airborne Velocity Messages of Subtypes "3" and "4." The values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: Heading Status Bit Verification – Data Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtypes "3" and "4" by providing airspeed and heading information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide non-zero airspeed data to the ADS-B System. This data should indicate non-supersonic velocity (less than 1000 knots) for testing Subtype=3 messages, and supersonic (greater than 1022 knots) for testing Subtype=4 messages. Provide heading input data to the ADS-B Transmitting Subsystem, and verify that output Airborne Velocity Messages have Message Bit 46 (ME Bit 14) correctly set to ONE (1).

Step 2: Heading Status Bit Verification – Data Not Available

Discontinue the input of heading information to the ADS-B Transmitting Subsystem. Verify that subsequent Airborne Velocity Messages have Message Bit 46 (ME Bit 14) correctly set to ZERO (0).

2.4.3.2.6.3.7 Verification of "Heading" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.7, §2.2.3.2.6.4.7, §2.2.5.1.15)

Purpose/Introduction:

This test will verify that the "Heading" subfield in Airborne Velocity Messages – Subtypes "3" and "4" is correctly set according to the encoding in Table 2-40. These test procedures are intended for use for Airborne Velocity Messages of Subtypes "3" and "4." The values of the input Velocity data should be set so as to generate Airborne Velocity Messages for all appropriate Subtype fields.

Measurement Procedure:

Step 1: Heading Verification – Data Equal ZERO

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=3 and "4" by providing airspeed information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid, non-zero airspeed data to the ADS-B System. This data should indicate non-supersonic airspeed (less than 1022 knots) for testing Subtype=3 messages, and supersonic airspeed (greater than 1022 knots) for testing Subtype=4 messages.

Provide heading input data with a value of ZERO to the ADS-B Transmitting Subsystem, and verify that the output "Heading" subfield in subsequent Airborne Velocity Messages is set to ZERO (binary 00 0000 0000). Also verify that the "Heading Status Bit" is set to ONE.

Step 2: Heading Verification – Discrete Values

This test will verify that the ADS-B Transmitting Subsystem properly encodes the Heading data for positive direction values.

Begin increasing the input Heading data so that it assumes all values identified in Table 2-141. Verify that the value transmitted in the "Heading" subfield of the ADS-B Airborne Velocity Messages corresponds to the binary coding of the input Heading in Table 2-141.

Table 2-141: "Heading" Subfield Discrete Values

Heading		
Coding		**Meaning**
(Binary)	(Decimal)	(Heading in degrees)
00 0000 0001	1	Heading = 0.3515625 degrees
00 0000 0010	2	Heading = 0.7031250 degrees
00 0000 0011	3	Heading = 1.0546875 degrees
00 0000 0101	5	Heading = 1.7578125 degrees
00 0000 1010	10	Heading = 3.5156250 degrees
00 0000 1111	15	Heading = 5.2734375 degrees
00 0101 0000	80	Heading = 28.1250000 degrees
00 0101 1010	90	Heading = 31.6406250 degrees
00 1010 0101	165	Heading = 58.0078125 degrees
00 1010 1010	170	Heading = 59.7656250 degrees
01 0101 0101	341	Heading = 119.8828125 degrees
01 1111 1111	511	Heading = 179.6484375 degrees
10 0000 0000	512	Heading = 180.0000000 degrees
10 0000 0001	513	Heading = 180.3515625 degrees
10 0000 0010	514	Heading = 180.7031250 degrees
10 0101 0101	597	Heading = 209.8828125 degrees
10 1010 1010	682	Heading = 239.7656250 degrees
11 0101 0101	853	Heading = 299.8828125 degrees
11 1010 1010	938	Heading = 329.7656250 degrees
11 1111 1110	1022	Heading = 359.2968750 degrees
11 1111 1111	1023	Heading = 359.6484375 degrees

Note: *The resolution of the raw data used as input to establish the Heading subfield may not be capable of setting values to exact multiples of 0.3515625 degrees. Where this is the case, the input should be set to values as close to the required values as possible.*

Step 3: Heading Verification – Incremental Checks

Note: *If the resolution of the Heading input to the ADS-B Transmitting Subsystem is exactly equal to 0.3515625 degrees, then this step* ***shall*** *not apply. If the resolution of the Heading input to the ADS-B Transmitting Subsystem is greater than 0.3515625 degrees, then the ½ LSB rule given in Note 2 of §2.2.3.2.6.3.7* ***shall*** *apply, and this step* ***shall*** *be used to ensure that the accuracy of the data is maintained such that it is not worse than ±½ LSB, where the LSB is the least significant bit of the "Heading" output subfield. In this case, this means that the output data must be accurate to within 1/2 of 0.3515625 degrees, i.e., within 0.17578125 degrees.*

Set up the ADS-B Transmitting Subsystem as in Step 1. Set the input heading to 0.3515625 degrees, and verify that the output "Heading" subfield is set to ONE (00 0000 0001). Increase the input value by the smallest increment possible, so that it assumes values greater than 0.3515625 degrees but less than 0.52734375 degrees.

Verify that for any value less than 0.52734375 degrees, the output of the "Heading" subfield does not change.

Increase the input value to the smallest possible value that is greater than 0.52734375 degrees.

Verify that the output "Heading" subfield in subsequent output messages is set to TWO (00 0000 0010).

Decrease the input so that it is set to the largest possible value that is less than 0.52734375 degrees.

Verify that the "Heading" subfield reverts to ONE (00 0000 0001).

2.4.3.2.6.3.8 Verification of "Airspeed Type" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.8, §2.2.3.2.6.4.8, §2.2.5.1.16, §2.2.5.1.17)

Purpose/Introduction:

This test procedure will verify that the "Airspeed Type" subfield in Airborne Velocity Messages, Subtypes "3" and "4" is correctly set to ZERO (0) to if the airspeed type is Indicated Airspeed (IAS), and to ONE (1) if the Airspeed Type is True Airspeed (TAS). These test procedures are intended for use for Airborne Velocity Messages of Subtypes "3" and "4." The values of the input Velocity data should be set so as to generate Airborne Velocity Messages with the appropriate Subtype field.

Measurement Procedure:

Step 1: Airspeed Type Verification – Indicated Airspeed

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtypes "3" and "4" by providing airspeed and heading information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide non-zero airspeed and heading data to the ADS-B System. This data should indicate non-supersonic velocity (less than 1022 knots) for testing Subtype=3 messages, and supersonic (greater than 1022 knots) for testing Subtype=4 messages.

Provide input airspeed data to the ADS-B Transmitting Subsystem in the form of "Indicated Airspeed" (IAS) data. Verify that the output Airborne Velocity Messages have an "Airspeed Type" subfield with a value of ZERO (0).

Step 2: Airspeed Type Verification – True Airspeed

Discontinue the input of IAS data to the ADS-B Transmitting Subsystem and instead provide input airspeed data in the form of "True Airspeed" (TAS) data.

Verify that subsequent Airborne Velocity Messages have an "Airspeed Type" subfield with a value of ONE (1).

2.4.3.2.6.3.9 Verification of "Airspeed" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.9, §2.2.5.1.16, §2.2.5.1.17)

Purpose/Introduction:

This test procedure will verify that the "Airspeed" subfield in Airborne Velocity Messages – Subtypes "3" and "4" is correctly encoded by the ADS-B Transmitting Subsystem.

Measurement Procedure:

Step 1: Airspeed Verification – Data Not Available

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing airspeed and heading information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages - Subtype=3 (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero, non-supersonic airspeed and heading data to the ADS-B System.

Discontinue Airspeed data and verify that when Airspeed data is not provided to the ADS-B Transmitting Subsystem, the "Airspeed" subfield in subsequent Airborne Velocity Messages – Subtype=3 is set to ZERO (binary 00 0000 0000).

Step 2: Airspeed Verification – Data Equal to ZERO

Setup the ADS-B Transmitting Subsystem as above and set the Airspeed input to represent a velocity of ZERO knots. Verify that the "Airspeed" subfield in subsequent Airborne Velocity Messages – Subtype=3 is set to ONE (1) (binary 00 0000 0001).

Step 3: Airspeed Verification – Discrete Values

Verify for each integer Airspeed (expressed in knots) in Table 2-142, that the system generates Airborne Velocity Messages with TYPE "19" and subtype "3" and that the "Airspeed" subfield coding in each such message is set equal to the corresponding binary coding value in the table.

Table 2-142: Discrete Values for "Airspeed" (subsonic)

Airspeed (IAS or TAS) (subsonic)		
Coding		**Meaning** (Airspeed in knots)
(Binary)	(Decimal)	
00 0000 0010	2	Airspeed = 1 knot
00 0000 0101	5	Airspeed = 4 knots
00 0000 1010	10	Airspeed = 9 knots
00 0000 1111	15	Airspeed = 14 knots
00 0101 0000	80	Airspeed = 79 knots
00 0101 1010	90	Airspeed = 89 knots
00 1010 0101	165	Airspeed = 164 knots
00 1010 1010	170	Airspeed = 169 knots
01 0101 0101	341	Airspeed = 340 knots
10 0101 0101	597	Airspeed = 596 knots
10 1010 1010	682	Airspeed = 681 knots
11 0101 0101	853	Airspeed = 852 knots
11 1010 1010	938	Airspeed = 937 knots
11 1111 1110	1022	Airspeed = 1021 knots

Step 4: Airspeed Verification - Part 4

Note: *If the nature of the inputs is such that a separate bit or "flag" type field is input to the transmitter to indicate "Indicated Airspeed" or "True Airspeed," the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the "Airspeed Type," the following step must be performed.*

Repeat Steps 2 and 3 so that each step is performed with Airspeed Type input data indicating both Indicated Airspeed (IAS) and True Airspeed (TAS).

2.4.3.2.6.3.10 Verification of "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.10, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.10.

2.4.3.2.6.3.11 Verification of "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.11, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.11.

2.4.3.2.6.3.12 Verification of "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.12, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.12.

2.4.3.2.6.3.13 Verification of "Reserved Bits-B" Subfield in Airborne Velocity Messages – Subtype=3 (§2.2.3.2.6.3.13)

Appropriate test procedures are provided in §2.4.3.2.6.1.13.

2.4.3.2.6.3.14 Verification of "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.14.

2.4.3.2.6.3.15 Verification of "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=3 (§2.2.3.2.6.3.15)

Appropriate test procedures are provided in §2.4.3.2.6.1.15.

2.4.3.2.6.4 Verification of ADS-B Airborne Velocity Message - Subtype=4 (§2.2.3.2.6.4)

Appropriate test procedures are provided in §2.4.3.2.6.4.1 through §2.4.3.2.6.4.15.

2.4.3.2.6.4.1 Verification of "TYPE" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.1)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.4.2 Verification of "Subtype" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.1, §2.2.3.2.6.4.2)

Appropriate test procedures are provided in §2.4.3.2.6.1.2.

2.4.3.2.6.4.3 Verification of "Intent Change Flag" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.3, §2.2.5.1.18)

Appropriate test procedures are provided in §2.4.3.2.6.1.3.

2.4.3.2.6.4.4 Verification of "Reserved Bit-A" Subfield in Airborne Velocity Messages – Subtype=4 (§2.2.3.2.6.4.4)

Appropriate test procedures are provided in §2.2.3.2.6.1.4.

2.4.3.2.6.4.5 Verification of "NAC_V" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.5, §2.2.5.1.19)

Appropriate test procedures are provided in §2.4.3.2.6.1.5.

2.4.3.2.6.4.6 Verification of "Heading Status Bit" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.6, §2.2.5.1.15)

Appropriate test procedures are provided in §2.4.3.2.6.3.6.

2.4.3.2.6.4.7 Verification of "Heading" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.7, §2.2.5.1.15)

Appropriate test procedures are provided in §2.4.3.2.6.3.7.

2.4.3.2.6.4.8 Verification of "Airspeed Type" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.8, §2.2.5.1.16, §2.2.5.1.17)

Appropriate test procedures are provided in §2.4.3.2.6.3.8.

2.4.3.2.6.4.9 Verification of "Airspeeed" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.9, §2.2.5.1.16, §2.2.5.1.17)

<u>Purpose/Introduction:</u>

This test will verify that the "Airspeed" subfield in Airborne Velocity Messages – Subtypes "3" and "4" is correctly encoded by the ADS-B Transmitting Subsystem.

<u>Measurement Procedure:</u>

<u>Step 1:</u> <u>"Airspeed" Verification – Data Not Available</u>

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages by providing airspeed and heading information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set up the system to enable broadcast of Airborne Velocity Messages - Subtype=4 (see additional information in §2.2.3.3.2.5, "ADS-B Velocity Message Broadcast Rate"). Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero airspeed and heading data to the ADS-B System.

Discontinue the input of Airspeed data and verify that when Airspeed data is not provided to the ADS-B Transmitting Subsystem, the "Airspeed" subfield in subsequent Airborne Velocity Messages – Subtype=4 is set to ZERO (binary 00 0000 0000).

Step 2: "Airspeed" Verification – Data Equal to ZERO

Setup the ADS-B Transmitting Subsystem as above and set the Airspeed input to represent a velocity of ZERO knots. Verify that the "Airspeed" subfield in subsequent Airborne Velocity Messages – Subtype=4 is set to 1.

Step 3: "Airspeed" Verification – Discrete Values

Verify for each integer "Airspeed" (expressed in knots) in Table 2-143, that the system generates Airborne Velocity Messages with TYPE "19" and subtype "4" and that the "Airspeed" subfield coding in each such message is set equal to the corresponding binary coding value in the table.

Table 2-143: Discrete Values for "Airspeed" (supersonic)

Airspeed (IAS or TAS) (supersonic)		
Coding		**Meaning** (Airspeed in knots)
(Binary)	(Decimal)	
00 0000 0010	2	Airspeed = 4 knots
00 0000 0101	5	Airspeed = 16 knots
00 0000 1010	10	Airspeed = 36 knots
00 0000 1111	15	Airspeed = 56 knots
00 0101 0000	80	Airspeed = 316 knots
00 0101 1010	90	Airspeed = 356 knots
00 1010 0101	165	Airspeed = 656 knots
00 1010 1010	170	Airspeed = 676 knots
01 0101 0101	341	Airspeed = 1,360 knots
10 0101 0101	597	Airspeed = 2,384 knots
10 1010 1010	682	Airspeed = 2,724 knots
11 0101 0101	853	Airspeed = 3,408 knots
11 1010 1010	938	Airspeed = 3,748 knots
11 1111 1110	1022	Airspeed = 4,084 knots

Verify that for 4 knot increases in the input value, that the "Airspeed" subfield in subsequent Airborne Velocity Messages of TYPE "19" is incremented by one from the previous value (i.e., that the value of the "Airspeed" subfield corresponds to the values given in the table in the above referenced section).

Verify that the "Airspeed" subfield in the output message is not incremented until the input value reaches a number corresponding to an even multiple of 4 knots.

Step 4: "Airspeed" Verification - Part 4

Continue to increase the value of the "Airspeed" Data input.

Verify that for discrete values above or equal to 4084 knots but below or equal to 4086 knots, the "Airspeed" subfield continues to be set to "1022" (binary 11 1111 1110).

Continue to increase the value of the "Airspeed" input.

Verify that for discrete input values representing an "Airspeed" greater than 4086 knots, up to the maximum possible input value, that the transmitter continues to generate Airborne Velocity Messages with a TYPE subfield equal to "19" and that the "Airspeed" subfield for all such messages is set to "1023" (binary 11 1111 1111).

Step 5: Airspeed Verification - Part 5

Note: *If the nature of the inputs is such that a separate bit or "flag" type field is input to the transmitter to indicate "Indicated Airspeed" or "True Airspeed," the following step is not necessary. However, if the transmitter must perform some interpretation of its inputs in order to determine the correct output value of the "Airspeed Type", the following step must be performed.*

Repeat Steps 2, 3 and 4 so that each step is performed with Airspeed Type input data indicating both Indicated Airspeed (IAS) and True Airspeed (TAS).

2.4.3.2.6.4.10 Verification of "Source Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.10, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.10.

2.4.3.2.6.4.11 Verification of "Sign Bit for Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.11, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.11.

2.4.3.2.6.4.12 Verification of "Vertical Rate" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.12, §2.2.5.1.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.12.

2.4.3.2.6.4.13 Verification of "Reserved Bits-B" Subfield in Airborne Velocity – Subtype=4 Messages (§2.2.3.2.6.4.13)

Appropriate test procedures are provided in §2.4.3.2.6.1.13.

2.4.3.2.6.4.14 Verification of "Difference From Barometric Altitude Sign Bit" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.14)

Appropriate test procedures are provided in §2.4.3.2.6.1.14.

2.4.3.2.6.4.15 Verification of "Difference From Barometric Altitude" Subfield in Airborne Velocity Messages - Subtype=4 (§2.2.3.2.6.4.15)

Appropriate test procedures are provided in §2.4.3.2.6.1.15.

2.4.3.2.6.5 Verification of ADS-B Airborne Velocity Messages - Subtypes "5, 6, & 7" (§2.2.3.2.6.5)

ADS-B Airborne Velocity Messages are not specified for Subtypes "5," "6" or "7" and **shall** be considered to be reserved for future expansion of Velocity Information Type Messages.

Appropriate test procedures will be added to this document as these messages are specified.

2.4.3.2.7 Verification of ADS-B Periodic Status and Event-Driven (§2.2.3.2.7)

Appropriate test procedures to validate the requirements of §2.2.3.2.7 are included in the following subparagraphs.

2.4.3.2.7.1 Verification of "Target State and Status" Messages (§2.2.3.2.7.1)

No specific test procedure is required to validate §2.2.3.2.7.1.

2.4.3.2.7.1.1 Verification of "TYPE" Subfield in Target State and Status Messages (§2.2.3.2.7.1.1)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting Subsystem correctly outputs Target State and Status Messages with the correct TYPE subfield data content in Message Bits 33 through 37 in DF=17 Messages for Transponder-Based Systems and DF=18 Messages for Non-Transponder-Based Systems. The TYPE subfield for the Target State and Status Messages should contain the value "29."

The ADS-B Transmitting Subsystem determines and outputs the "TYPE" subfield based upon the input it receives from the type of Navigational System source that may interface to the system. The ADS-B Transmitting Subsystem may receive the "TYPE" subfield directly through an external interface instead of dynamically determining the "TYPE" subfield.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Target State and Status Messages by providing valid trajectory information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status.

Verify that the "TYPE" subfield in the ADS-B Message correctly matches the "TYPE" subfield value of 29 (binary 11101). See Table 2-16.

2.4.3.2.7.1.2 Verification of the "Subtype" Subfield in Target State and Status Messages (§2.2.3.2.7.1.2)

Purpose/Introduction:

The "Subtype" subfield in the Target State and Status Message is encoded in accordance with Table 2-45.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Target State and Status Messages by providing valid trajectory information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status.

Verify that the "TYPE" subfield in the ADS-B Message is set to a value of 29 (binary 11101) and that the "Subtype" subfield is set to a value of ONE (binary 01).

2.4.3.2.7.1.3 Verification of the Target State and Status (Subtype=1) Format (§2.2.3.2.7.1.3)

Appropriate test procedures required to validate the requirements of §2.2.3.2.7.1.3 are included in §2.4.3.2.7.1.3.1 through §2.4.3.2.7.1.3.12.

2.4.3.2.7.1.3.1 Verification of the "SIL Supplement" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.1, §2.2.3.2.7.2.14, §2.2.5.1.41)

Purpose/Introduction:

The "SIL Supplement" (Source Integrity Level Supplement) subfield is a 1-bit ("ME" bit 8, Message bit 40) field that defines whether the reported SIL probability is based on a "per hour" probability or a "per sample" probability as defined in Table 2-46. The purpose of the following test procedure is to verify that the "SIL Supplement" subfield is being set appropriately.

Measurement Procedure:

Step 1: Target State and Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid Mode Control Panel Selected Altitude data in order to initialize transmission of Target State and Status Messages.

Step 2: Verification of SIL Supplement for "Per Hour" Probability

Via the appropriate data input interface, provide the ADS-B Transmitting Subsystem with valid data indicating that the integrity of the geometric position source is being established on a "Per Hour" basis.

> ***Note:*** *If an actual interface is not used to provide "SIL Supplement" information, then ensure that a GNSS position source is being used to provide geometric positon data for the purpose of establishing position in the Airborne and Surface Position messages. (See §2.2.5.1.42)*.

Verify that the "SIL Supplement" subfield ("ME" bit 8, Message bit 40) in the Target State and Status Messages is set to "ZERO" (0).

Step 3: Verification of SIL Supplement for "Per Sample" Probability

Via the appropriate data input interface, provide the ADS-B Transmitting Subsystem with valid data indicating that the integrity of the geometric position source is being established on a "Per Sample" basis.

> ***Note:*** *If an actual interface is not used to provide "SIL Supplement" information, then ensure that a Non-GNSS position source is being used to provide geometric positon data for the purpose of establishing position in the Airborne and Surface Position messages. (See §2.2.5.1.42).*

Verify that the "SIL Supplement" subfield ("ME" bit 8, Message bit 40) in the Target State and Status Messages is set to "ONE" (1).

2.4.3.2.7.1.3.2 Verification of the "Selected Altitude Type" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.2)

Appropriate test procedures to verify setting of the Selected Altitude Type subfield in the Target State and Status Messages are provided in §2.4.3.2.7.1.3.3.

2.4.3.2.7.1.3.3 Verification of the "MCP/FCU Selected Altitude or FMS Selected Altitude" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.3, §2.2.5.1.42)

Purpose/Introduction:

The purpose of the following procedure is to verify that Selected Altitude data is properly reported in accordance with §2.2.3.2.7.1.3.3.

Measurement Procedure:

Step 1: Setup of MCP / FCU Selected Altitude Data

For each line Item # in Table 2.4.3.2.7.1.3.3-1, via the appropriate interface, provide the ADS-B Transmitting Subsystem with Mode Control Panel Selected Altitude having a value as indicated in the "Data Value" (feet) Column in Table 2.4.3.2.7.1.3.3-1.

Table 2.4.3.2.7.1.3.3-1: MCP/FCU Selected Altitude in Target State and Status Messages (ARINC Label '102')

Item #	Generic MCP / FCU Selected Altitude Input (BNR)			Target State and Status Encoding of MCP / FCU Selected Altitude		
	Type of Value	Status	Data Value (feet)	TYPE (bit 9)	Decimal Value (feet)	Binary Value (bit 10 ------ 20)
1	Basic	Valid	43,648.00	0	43,648.00	101 0101 0101
2	Basic	Valid	21,792.00	0	21,792.00	010 1010 1010
3	Basic	Valid	23,352.00	0	23,352.00	011 0111 0111
5	Basic	Valid	65,472.00	0	65,472.00	111 1111 1111
6	Basic	Rounded (1/4 LSB)	52,392.00	0	52,384.00	110 0110 0110
7	Basic	Rounded (1/2 LSB)	52,400.00	0	52,416.00	110 0110 0111
8	Invalid	Invalid	21,792.00	0	0.00	000 0000 0000

Step 2: Setup of FMS Selected Altitude Data

For each line Item # in Table 2.4.3.2.7.1.3.3-2, via the appropriate interface, provide the ADS-B Transmitting Subsystem with FMS Selected Altitude having a value as indicated in the "Data Value" (feet) Column in Table 2.4.3.2.7.1.3.3-2. Provide at least one data value from Table 2.4.3.2.7.1.3.3-2 while provided the data for Line Item #1 through 7 in Table 2.4.3.2.7.1.3.3-1. Do not provide any data from Table 2.4.3.2.7.1.3.3-2 when providing data for Line Item #8 in Table 2.4.3.2.7.1.3.3-1.

Table 2.4.3.2.7.1.3.3-2: FMS Selected Altitude in Target State and Status Messages (ARINC Label '102')

Item #	Generic FMS Selected Altitude Input (BNR)			Target State and Status Encoding of FMS Selected Altitude		
	Type of Value	Status	Data Value (feet)	TYPE (bit 9)	Decimal Value (feet)	Binary Value (bit 10 ------ 20)
1	Basic	Valid	37,088.00	1	37,088.00	100 1000 1000
2	Basic	Valid	13,600.00	1	13,600.00	001 1010 1010
3	Basic	Valid	22,880.00	1	22,880.00	010 1100 1100
5	Basic	Valid	60,032.00	1	60,032.00	111 0101 0101
6	Basic	Rounded (1/4 LSB)	25,640.00	1	25,632.00	011 0010 0010
7	Basic	Rounded (1/2 LSB)	25,648.00	1	25,664.00	011 0010 0011
8	Invalid	Invalid	13,600.00	1	0.00	000 0000 0000

Step 3: Verification of MCP / FCU Selected Altitude Data

For each line Item # given in Table 2.4.3.2.7.1.3.3-1, verify that Target State and Status Messages are properly transmitted having:

(1). Selected Altitude Type, (bit 9), set as indicated in the "TYPE" (bit 9) Column of Table 2.4.3.2.7.1.3.3-1.

(2). Selected Altitude Binary Value, set as indicated in the “Binary Value” (bit 10 --- 20) Column of Table 2.4.3.2.7.1.3.3-1.

Step 4: Discontinue MCP / FCU Selected Altitude Data

Discontinue the provisioning of all MCP / FCU Selected Altitude data as was provided in Step 1, e.g., Table 2.4.3.2.7.1.3.3-1.

Step 5: Verification of FMS Selected Altitude Data

For each line Item # given in Table 2.4.3.2.7.1.3.3-2, verify that Target State and Status Messages are properly transmitted having:

(1). Selected Altitude Type, (bit 9), set as indicated in the “TYPE” (bit 9) Column of Table 2.4.3.2.7.1.3.3-2, and

(2). Selected Altitude Binary Value, set as indicated in the “Binary Value” (bit 10 --- 20) Column of Table 2.4.3.2.7.1.3.3-2.

Step 6: Discontinue FMS Selected Altitude Data

Discontinue the provisioning of all MCP / FCU Selected Altitude data as was provided in Step 1, e.g., Table 2.4.3.2.7.1.3.3-1.

Step 7: Verification of Selected Altitude Data – Data Lifetime

At least 5 seconds after the execution of Step “f,” verify that Target State and Status Messages are properly transmitted having:

(1). Selected Altitude Type, (bit 9), set to ZERO (0).

(2). Selected Altitude Binary Value, set to ZERO (0).

2.4.3.2.7.1.3.4 Verification of the “Barometric Pressure Setting (Minus 800 millibars)” Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.4, §2.2.5.1.43)

Purpose/Introduction:

The purpose of the following procedure is to verify that Selected Altitude data is properly reported in accordance with §2.2.3.2.7.1.3.4.

Measurement Procedure:

Step 1: Setup of Barometric Pressure Setting Data

For each line Item # in Table 2.4.3.2.7.1.3.4, via the appropriate interface, provide the ADS-B Transmitting Subsystem with Barometric Pressure Setting data having a value as indicated in the “Data Value” (millibars) Column in Table 2.4.3.2.7.1.3.4.

Table 2.4.3.2.7.1.3.4: Barometric Pressure Setting in Target State and Status Messages (ARINC Label '234')

Item #	Barometric Pressure Setting Data Input			Target State and Status Encoding of Barometric Pressure Setting	
	Type of Value	Status	Data Value (millibars)	Decimal Value (millibars) (minus 800)	Binary Value (bit 21 ------ 29)
1	Basic	Valid	942.7	142.4	0 1011 0001
2	Basic	Valid	923.2	123.2	1 0101 0101
3	Basic	Valid	1208.0	408.0	1 1111 1111
5	Basic	Valid	927.2	127.2	0 1010 1010
6	Basic	Rounded (1/4 LSB)	1099.4	299.2	1 0111 0111
7	Basic	Rounded (1/2 LSB)	1099.6	300.0	1 0111 1000
8	Invalid	Valid	1209.6	0.000	0 0000 0000
9	Invalid	Valid	799.6	0.000	0 0000 0000
10	Invalid	Invalid	927.2	0.00	0 0000 0000

Step 2: Verification of Barometric Pressure Setting Data

For each line Item # given in Table 2.4.3.2.7.1.3.4, verify that Target State and Status Messages are properly transmitted having Barometric Pressure Setting Binary Value set as indicated in the "Binary Value" (bit 21 --- 29) Column of Table 2.4.3.2.7.1.3.4.

Step 3: Discontinue Barometric Pressure Setting Data

Discontinue the provisioning of all Barometric Pressure Setting data as was provided in Step 1, e.g., Table 2.4.3.2.7.1.3.4.

Step 4: Verification of Barometric Pressure Setting Data – Data Lifetime

At least 5 seconds after the execution of Step "3," verify that Target State and Status Messages are properly transmitted having Barometric Pressure Setting Binary Value (bit 21 --- 29) set to ZERO (0).

2.4.3.2.7.1.3.5 Verification of the "Selected Heading Status" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.5)

Appropriate test procedures to verify setting of the Selected Heading Status in Target State and Status Messages are provided in §2.4.3.2.7.1.3.7.

2.4.3.2.7.1.3.6 Verification of the "Selected Heading Sign" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.6)

Appropriate test procedures to verify setting of the Selected Heading Sign in Target State and Status Messages are provided in §2.4.3.2.7.1.3.7.

2.4.3.2.7.1.3.7 Verification of the "Selected Heading" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.7, §2.2.5.1.44)

Purpose/Introduction:

The purpose of the following test procedure is to verify that Selected Heading data provided in the Target State and Status Messages are properly reported in accordance with §2.2.3.2.7.1.3.5 through §2.2.3.2.7.1.3.7.

Measurement Procedure:

Step 1: Setup of Selected Heading Data

For each line Item # in Table 2.4.3.2.7.1.3.7, via the appropriate interface, provide the ADS-B Transmitting Subsystem with Selected Heading data having a value as indicated in the "Data Value" (degrees) Column in Table 2.4.3.2.7.1.3.7.

Table 2.4.3.2.7.1.3.7: Selected Heading Data in Target State and Status Messages (ARINC Label '101')

Item #	Generic Selected Heading Input (degrees) [binary (BNR)]				Target State and Status Encoding of Selected Heading				
	Type of Value	Status	Sense (Note 1)	Data Value (degrees)	Sense (Note 1)	Decimal Value (degrees)	Status (bit 30)	Sign (bit 31) (Note 2)	Binary Value (bits 32 --- 39)
1	Basic	Valid	West (CCW)	-120.234375 (239.765625)	Left	-120.234375 (239.765625)	1	1	0101 0101
2	Basic	Valid	East (CW)	119.53125	Right	119.53125	1	0	1010 1010
3	Basic	Valid	West (CCW)	-24.609375 (335.390625)	Left	-24.609375 (335.390625)	1	1	1101 1101
4	Basic	Valid	West (CCW)	-90.000 (270.000)	Left	-90.000 (270.000)	1	1	1000 0000
5	Basic	Valid	East (CW)	135.000	Right	135.000	1	0	1100 0000
6	Rounded (1/4 LSB)	Valid	West (CCW)	-120.0585937 (239.94140625)	Left	-120.234375 (239.765625)	1	1	0101 0101
7	Rounded (1/2 LSB)	Valid	West (CCW)	-119.8828125 (240.1171875)	Left	-119.53125 (240.46875)	1	1	0101 0110
8	Invalid	Invalid	East (CW)	119.53125	Not Applicable	0.000	0	0	0000 0000

Notes:

1. *Input data Sense refers to (a) Positive, being Clockwise (CW), commonly meaning East of North, or (b) Negative, being Counter-Clockwise (CCW), commonly meaning West of North.*
2. *The Sign Bit is "1" for Negative, West of North, or Counter-Clockwise (CCW). The Sign Bit is "0" for Positive, East of North, or Clockwise (CW).*

Step 2: Verification of Selected Heading Status, Sign, and Data

For each line Item # given in Table 2.4.3.2.7.1.3.7, verify that Target State and Status Messages are properly transmitted having:

(1). Selected Heading Status (“ME” bit 30, Message Bit 62) set as indicated in the “Status (bit 30)” Column of Table 2.4.3.2.7.1.3.7,

(2). Selected Heading Sign (“ME” bit 31, Message Bit 63) set as indicated in the “Sign (bit 31)” Column of Table 2.4.3.2.7.1.3.7, and

(3). Selected heading Data (“ME” bits 32 –through- 39, Message bits 64 –through- 71) set as indicated in the “Binary Value (bits 32---39)” Column of Table 2.4.3.2.7.1.3.7.

Step 3: Discontinue Selected Heading Data

Discontinue the provisioning of all Selected Heading information (e.g., Status, Sign, Data) as was provided in Step 1, e.g., Table 2.4.3.2.7.1.3.7.

Step 4: Verification of Selected Heading – Data Lifetime

At least 5 seconds after the execution of Step “3,” verify that Target State and Status Messages are properly transmitted having all Selected Heading information (“ME” bits 30 through 39, Message bits 62 through 71) set to ZERO (0).

2.4.3.2.7.1.3.8 Verification of the “NAC_P” Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.8, §2.2.5.1.34)

Purpose/Introduction:

The “NAC_P ” subfield in the Target State and Status Message is encoded in accordance with Table 2-71.

Measurement Procedure:

Step 1: Target State and Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid Mode Control Panel Selected Altitude data in order to initialize transmission of Target State and Status Messages.

Step 2: Verification of NAC_P Transmission

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with each of the EPU values indicated in Table 2-71.

Verify that for each input NAC_P parameter that is specified by the EPU value in Table 2-71, that the system generates ADS-B Messages with the NAC_P subfield set equal to the corresponding binary coding value shown in Table 2-71.

Step 3: Verification of NAC_P – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for valid trajectory information for a period of at least 5 seconds. Verify that ME bits 40 through 43 in the Target State and Status Message are set to a value of ZERO (binary 0000).

2.4.3.2.7.1.3.9 Verification of the "NIC_{BARO}" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.9, §2.2.5.1.35)

Purpose/Introduction:

The "NIC_{BARO}" (Barometric Altitude Integrity Code) subfield in the Target State and Status Message is used to indicate whether or not the barometric pressure altitude being reported in the Airborne Position Message (§2.2.3.2.3) has been cross checked against another source of pressure altitude. The "NIC_{BARO} " subfield is encoded in accordance with Table 2-73, as specified in the Aircraft Operational Status Message.

Measurement Procedure:

Step 1: Target State and Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid Mode Control Panel Selected Altitude data in order to initialize transmission of Target State and Status Messages.

Step 2: Verification of NIC_{BARO} Transmission

Operationally select Barometric Pressure Altitude as the Primary Altitude information and verify that the "ALTITUDE TYPE" field in ME bit 10 is set to ZERO (0).

Input to the ADS-B Transmitting Subsystem the condition that signifies that the barometric pressure altitude has been crosschecked against another source of pressure altitude. Verify that the NIC_{BARO} field ME bit 44 is set to ONE (1).

Input to the ADS-B Transmitting Subsystem the condition that signifies that the barometric pressure altitude has NOT been crosschecked against another source of pressure altitude. Verify that the NIC_{BARO} field ME bit 44 is set to ZERO (0).

Step 3: Verification of NIC_{BARO} – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input used in step 1 for a period of at least 5 seconds. Verify that ME bit 44 in the Target State and Status Message is set to a value of ZERO (0).

2.4.3.2.7.1.3.10 Verification of the "SIL" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.10, §2.2.3.2.7.2.9, §2.2.5.1.40)

Purpose/Introduction:

The "SIL" (Source Integrity Level) subfield is a 2-bit ("ME" bits 45 and 46, Message bits 77 and 78) field that **shall** be used to define the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. The SIL will address the Signal-in-Space, and will be the higher of the faulted or fault free probability of the Signal-In-Space causing the NIC radius of containment to be exceeded. The "SIL" subfield is encoded in accordance with Table 2-72, as specified in the ADS-B Aircraft Operational Status Message. For installations where the SIL value is being dynamically updated, if an update has not been received from an on-board data source for SIL within the past 5 seconds, then the SIL subfield is set to a value of ZERO (0), indicating "Unknown."

Measurement Procedure:

Step 1: Target State and Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid Mode Control Panel Selected Altitude data in order to initialize transmission of Target State and Status Messages.

Step 2: Verification of SIL Transmission

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid data to establish each of the "SIL" conditions indicated in Table 2-72.

Verify that for each "SIL" parameter input condition that is specified by the probability of exceeding the R_C Integrity Radius of Containment without detection (i.e., the value in Table 2-72), that the system generates ADS-B Messages with the "SIL" subfield set equal to the corresponding binary coding value shown in Table 2-72.

Step 3: Verification of SIL– Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input in step 1 for a period of at least 5 seconds. Verify that ME bits 45 and 46 in the Target State and Status Message are set to a value of ZERO (binary 00).

2.4.3.2.7.1.3.11 Verification of the "Status of MCP/FCU Mode Bits" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.11, §2.2.5.1.45)

Purpose/Introduction:

The purpose of the following test procedure is to verify that "Status of MCP / FCU Mode Bits" information is properly reported in accordance with §2.2.3.2.7.1.3.11.

Measurement Procedure:

Step 1: Initialization with NO Status

Ensure that No information is being provided to the ADS-B Transmitting Subsystem that would indicate the status of Autopilot Engaged, VNAV Mode Engaged, Altitude Hold Mode, or Approach Mode.

Step 2: Verification of NO Status

Verify that Target State and Status Messages are properly transmitted having the "Status of MCP / FCU Mode Bits" subfield ("ME" bit 47, Message bit 79) set to ZERO (0).

Step 3: Initialization with Status

Via the appropriate interface(s), provide the ADS-B Transmit Subsystem with the status of Autopilot Engaged, VNAV Mode Engaged, Altitude Hold Mode and Approach Mode with the status indicating "Not Engaged" for each of the status parameters.

Step 4: Verification of Provided Status

Verify that Target State and Status Messages are properly transmitted having the "Status of MCP / FCU Mode Bits" subfield ("ME" bit 47, Message bit 79) set to ONE (1).

2.4.3.2.7.1.3.12 Verification of the "Autopilot Engaged" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.12, §2.2.5.1.45)

Purpose/Introduction:

The purpose of the following test procedure is to verify that "Autopilot Engaged" information is properly reported in accordance with §2.2.3.2.7.1.3.12.

Measurement Procedure:

Step 1: Initialization with Autopilot NOT Engaged

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with the information necessary to establish that the Autopilot is Not Engaged.

Step 2: Verification of Autopilot NOT Engaged

Verify that Target State and Status Messages are properly transmitted having the "Autopilot Engaged" subfield ("ME" bit 48, Message bit 80) set to ZERO (0).

Step 3: Initialization with Autopilot Engaged

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that the Autopilot is Engaged.

Step 4: Verification of Autopilot Engaged

Verify that Target State and Status Messages are properly transmitted having the "Autopilot Engaged" subfield ("ME" bit 48, Message bit 80) set to ONE (1).

2.4.3.2.7.1.3.13 Verification of the "VNAV Mode Engaged" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.13, §2.2.5.1.45)

Purpose/Introduction:

The purpose of the following test procedure is to verify that "VNAV Mode Engaged" information is properly reported in accordance with §2.2.3.2.7.1.3.13.

Measurement Procedure:

Step 1: Initialization with VNAV Mode Not Engaged

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that the VNAV Mode is Not Engaged.

Step 2: Verification of VNAV Mode Not Engaged

Verify that Target State and Status Messages are properly transmitted having the "VNAV Mode Engaged" subfield ("ME" bit 49, Message bit 81) set to ZERO (0).

Step 3: Initialization with VNAV Mode Engaged

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that the VNAV Mode is Engaged.

Step 4: Verification of VNAV Mode Engaged

Verify that Target State and Status Messages are properly transmitted having the "VNAV Mode Engaged" subfield ("ME" bit 49, Message bit 81) set to ONE (1).

2.4.3.2.7.1.3.14 Verification of the "Altitude Hold Mode" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.14, §2.2.5.1.45)

Purpose/Introduction:

The purpose of the following test procedure is to verify that "Altitude Hold" information is properly reported in accordance with §2.2.3.2.7.1.3.14.

Measurement Procedure:

Step 1: Initialization with Altitude Hold Mode Not Engaged

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that the Altitude Hold Mode is Not Engaged.

Step 2: Verification of VNAV Not Engaged

Verify that Target State and Status Messages are properly transmitted having the "Altitude Hold" subfield ("ME" bit 50, Message bit 82) set to ZERO (0).

Step 3: Initialization with Altitude Hold Mode Engaged

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that the Altitude Hold Mode is Engaged.

Step 4: Verification of Altitude Hold Mode Engaged

Verify that Target State and Status Messages are properly transmitted having the "Altitude Hold" subfield ("ME" bit 50, Message bit 82) set to ONE (1).

2.4.3.2.7.1.3.15 Verification of the "Reserved for ADS-R Flag" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.15)

Purpose/Introduction:

ADS-B 1090ES Rebroadcast Messages are transmitted from a 1090ES ADS-B Ground Station as a rebroadcast of an ADS-B Message that was received by that Ground Station on an alternate ADS-B Data Link. The Airborne ADS-B Transmitting Subsystem will always transmit a ZERO (0) in "ME" bit 51 of the Target State and Status Message.

These test procedures verify that ME bit 51 of the transmitted DF=17 Target State and Status Message from an Airborne ADS-B Transmitting Subsystem is always ZERO (0).

Measurement Procedure:

Step 1: Target State and Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid Mode Control Panel Selected Altitude data in order to initialize transmission of Target State and Status Messages.

Step 2: Verification of ADS-R Flag

Set the ADS-B Transmitting Subsystem to Airborne status. Verify that Target State and Status Messages are broadcast with the "ME" bit 51 (Message bit 83) set to ZERO (0).

2.4.3.2.7.1.3.16 Verification of the "Approach Mode" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.16, §2.2.5.1.45)

Purpose/Introduction:

The purpose of the following test procedure is to verify that "Approach Mode" information is properly reported in accordance with §2.2.3.2.7.1.3.16.

Measurement Procedure:

Step 1: Initialization with Approach Mode Not Engaged

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with the information necessary to establish that the Approach Mode is Not Engaged.

Step 2: Verification of Approach Mode Not Engaged

Verify that Target State and Status Messages are properly transmitted having the "Approach Mode" subfield ("ME" bit 52, Message bit 84) set to ZERO (0).

Step 3: Initialization with Approach Mode Engaged

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that the Approach Mode is Engaged.

Step 4: Verification of Approach Mode Engaged

Verify that Target State and Status Messages are properly transmitted having the "Approach Mode" subfield ("ME" bit 52, Message bit 84) set to ONE (1).

2.4.3.2.7.1.3.17 Verification of the "TCAS Operational" Subfield in Target State and Status Messages (§2.2.3.2.7.1.3.17, §2.2.5.1.48)

Purpose/Introduction:

The purpose of the following test procedure is to verify that "TCAS Operational" information is properly reported in accordance with §2.2.3.2.7.1.3.17.

Measurement Procedure:

Step 1: Initialization with TCAS Not Operational

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with the information necessary to establish that TCAS is Not Operational.

Step 2: Verification of TCAS Not Operational

Verify that Target State and Status Messages are properly transmitted having the "TCAS Operational" subfield ("ME" bit 55, Message bit 85) set to ZERO (0).

Step 3: Initialization with TCAS Operational

Via the appropriate interface, provide the ADS-B transmit subsystem with the information necessary to establish that TCAS is Operational.

Step 4: Verification of TCAS Operational

Verify that Target State and Status Messages are properly transmitted having the "TCAS Operational" subfield ("ME" bit 53, Message bit 85) set to ONE (1).

2.4.3.2.7.1.3.18 Verification of "Reserved" Bits in Target State and Status Messages (§2.2.3.2.7.1.3.18)

Purpose/Introduction:

The purpose of this test procedure is to verify that the "Reserved" bits ("ME" bits 54 through 56, Message bits 86 through 88) are set to ZERO (000) in this version of these MOPS.

Measurement Procedure:

Step 1: Target State and Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid Mode Control Panel Selected Altitude data in order to initialize transmission of Target State and Status Messages.

Step 2: Verification of "Reserved" Bits

Set the ADS-B Transmitting Subsystem to Airborne status. Verify that Target State and Status Messages are broadcast with the "ME" bits 54 through 56 (Message bit 86 through 88) set to ZERO (0).

2.4.3.2.7.1.4 Verification of the Reserved for TYPE=29 and Subtype>1 Message Formats (§2.2.3.2.7.1.4)

No specific test procedures are required to validate §2.2.3.2.7.1.4.

2.4.3.2.7.2 Verification of "Aircraft Operational Status" Messages (§2.2.3.2.7.2)

No specific test procedure is required to validate §2.2.3.2.7.2.

2.4.3.2.7.2.1 Verification of "TYPE" Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.1)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting Subsystem correctly outputs Aircraft Operational Status Messages with the correct TYPE Code subfield data content in

Message Bits 33 through 37 in DF=17 Messages for Transponder-Based Systems and DF=18 Messages for Non-Transponder-Based Systems.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages. Verify that the output Aircraft Operational Status Messages have a TYPE Code subfield which contains the value "31."

2.4.3.2.7.2.2 Verification of "Subtype" Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.2, §2.2.5.1.20)

Purpose/Introduction:

The "Subtype" Code subfield is used to indicate various subtypes of Aircraft Operational Status Messages. As defined in these MOPS, Subtype=0 indicates Airborne participants and Subtype=1 indicates Surface participants.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages. Set the ADS-B Transmitting Subsystem to Airborne Status. Verify that ME bits 6 through 8 are set to ZERO (binary 000) in the next output Aircraft Operational Status Message.

Repeat this step setting the ADS-B Transmitting Subsystem to "On-Ground" status. Verify that ME bits 6 through 8 are set to ONE (binary 001) in the next output Aircraft Operational Status Message.

2.4.3.2.7.2.3 Verification of "CAPABILITY CLASS (CC)" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3)

Appropriate test procedures required to validate the requirements of §2.2.3.2.7.2.3 are provided in the following subparagraphs.

2.4.3.2.7.2.3.1 Verification of the "Reserved" CC Code Subfield in Aircraft Operational Status Message (§2.2.3.2.7.2.3.1, §2.2.5.1.21)

Purpose/Introduction:

Within the Capability Class subfield, bits are reserved for setting by future versions of these MOPS. ADS-B equipment conforming to this version of these MOPS (RTCA DO-260B) **shall** set these reserved bits to ALL ZEROs.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Verify that ME bits 9, 10, 13, 14 and 20 – 24 are set to ALL ZEROs.

2.4.3.2.7.2.3.2 Verification of the "TCAS Operational" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.2)

Appropriate test procedures required to validate the requirements of §2.2.3.2.7.2.3.2 are included in §2.4.3.2.7.1.3.17.

2.4.3.2.7.2.3.3 Verification of "1090ES IN" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.3, §2.2.5.1.23)

Purpose/Introduction:

The CC Code for "1090ES IN" in Aircraft Operational Status Messages (TYPE=31, Subtype=0 or 1) is a 1-bit field ("ME" bit 12, Message bit 44) that **shall** be set to ONE (1) as specified in Table 2-63 if the transmitting aircraft has the capability to receive ADS-B 1090ES Messages. Otherwise, this CC code **shall** be ZERO (0).

Measurement Procedure:

Step 1: Verfification of the "1090ES IN" CC Code Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages (TYPE=31, Subtype=0, indicating airborne participants) by providing valid operational status information at the nominal update rate. Set the ADS-B Transmitting Subsystem to Airborne status. Provide appropriate data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation IS NOT fitted with a properly functioning ADS-B 1090ES Message Receiving Subsystem Verify that ME bit 12 is set to ZERO (0). Repeat this step while indicating that the installation IS fitted with the capability to receive ADS-B 1090ES Messages and verify that ME bit 12 is set to ONE (1).

Set the ADS-B Transmitting Subsystem to Surface status. Repeat the above procedure while transmitting Aircraft Operational Status Messages with TYPE=31 and Subtype=1, indicating surface participants.

Step 2: Verification of "1090ES IN" CC Code – Data Lifetime

Rerun the Test Procedures in Step 1 for both the Airborne and Surface modes. In each case, remove the data source input for "1090ES IN" CC Code information for a period of at least 5 seconds. Verify that ME bit 12 in the Aircraft Operational Status Message is set to a value of ZERO (0).

2.4.3.2.7.2.3.4 Verification of the "ARV Report Capability" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.4, §2.2.5.1.24)

Purpose/Introduction:

The "ARV Report Capability" subfield of the CC Codes subfield is a 1-bit Boolean flag that expresses the capability of the ADS-B Subsystem for sending messages to support Air Reference Velocity Reports, and is encoded as specified in Table 2-64.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation DOES NOT have the capability to send messages that support Air Referenced Velocity Reports.

Verify that the ME bit 15 (Message bit 47) is set to ZERO (0). Repeat this step while indicating that the installation DOES have the capability to send messages that support Air Referenced Velocity Reports, and verify that "ME" bit 15 (Message bit 47) is set to ONE (1).

2.4.3.2.7.2.3.5 Verification of the "TS Report Capability" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.5)

Purpose/Introduction:

The "Target State (TS) Report Capability" subfield of the CC Codes subfield is a 1-bit Boolean flag in the "airborne" format of the Aircraft Operational Status Message (TYPE=31, Subtype=0) that expresses the capability of the ADS-B Subsystem for sending messages to support Target State Reports, and is encoded as specified in Table 2-65.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation DOES NOT have the capability to send messages that support Target State Reports.

Verify that "ME" bit 16 (Message bit 48) is set to ZERO (0). Repeat this step while indicating that the installation DOES have the capability to send messages that support Target State Reports and verify that ME bit 16 (Message bit 48) is set to ONE (1).

2.4.3.2.7.2.3.6 Verification of the "TC Report Capability" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.6)

Purpose/Introduction:

The "Trajectory Change (TC) Report Capability" subfield of the CC Code subfield is a 2-bit ("ME" bits 17 and 18) subfield in the "airborne" format of the Aircraft Operational Status Message (TYPE=31, Subtype=0) and is defined in the ADS-B MASPS (RTCA DO-242A) as specified in Table 2-66. For these MOPS the subfield is set to ZERO (binary 00).

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Verify that ME bits 16 and 17 are set to ZERO (binary 00).

2.4.3.2.7.2.3.7 Verification of the "Position Offset Applied" CC Code Subfield in Surface Aircraft Operational Status Messages (§2.2.3.2.7.2.3.7)

Purpose/Introduction:

The "Position Offset Applied" (POA) subfield of the CC Code subfield of the "surface" format Aircraft Operational Status Message (TYPE=31, Subtype=1) is a 1-bit Boolean flag that the ADS-B Transmitting Subsystem sets to ONE (1) as specified in Table 2-67 if the position that it is transmitted in the ADS-B Surface Position Message (§2.2.3.2.4) is known to be the position of the ADS-B participant's ADS-B Position Reference Point (RTCA DO-242A, §3.4.4.9.7) rather than, for example, the position of the antenna of the navigation receiver. Otherwise, the ADS-B Transmitting Subsystem sets this flag to ZERO (0).

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation transmits position in the ADS-B Surface Position Message that IS NOT known to be referenced to the ADS-B Position Reference Point of the A/V. Verify that ME bit 11 (Message bit 43) is set to ZERO (0).

Repeat this step while indicating that the installation transmits position in the ADS-B Surface Position Message that IS known to be referenced to the ADS-B Position Reference Point of the A/V. Verify that ME bit 11 (Message bit 43) is set to ONE (1).

2.4.3.2.7.2.3.8 Verification of the "B2 Low" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.8)

Purpose/Introduction:

The "B2 Low" subfield ("ME" bit 15) of the CC Code subfield in the "surface" version of the Aircraft Operational Status Message (TYPE=31, Subtype=1) is a 1-bit Boolean flag that the ADS-B Transmitting Subsystem sets to ONE (1) if the Transmitting Subsystem is a Non-Transponder-Based Transmitting Subsystem on a Ground Vehicle (Class B2) transmitting with less than 70 watts of transmit power. Otherwise, this bit is set to ZERO (0).

Measurement Procedure:

For a Non-Transponder-Based Class B2 Transmitting Subsystem known to have a transmitting power of 70 watts or more, configure the Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid information at the nominal update rate. Provide the data externally at the interface to the ADS-B Transmitting Subsystem to enable transmission of Aircraft Operational Status Messages. Verify that ME bit 15 (Message bit 47) is set to ZERO (0).

For a Non-Transponder-Based Class B2 Transmitting Subsystem known to have a transmitting power of less than 70 watts, configure the Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid information at the nominal update rate. Provide the data externally at the interface to the ADS-B Transmitting Subsystem to enable transmission of Aircraft Operational Status Messages. Verify that ME bit 15 (Message bit 47) is set to ONE (1).

2.4.3.2.7.2.3.9 Verification of "NAC_V" CC Code Subfield in Surface Aircraft Operational Status Messages (§2.2.3.2.7.2.3.9, §2.2.5.1.19)

Purpose/Introduction:

The "NAC_V" subfield is used to indicate the Navigation Accuracy Category for Velocity as specified in Table 2-25. These test procedures are intended for use for Surface Aircraft Operational Status Messages for Version 2 ADS-B Transmit Subsystems.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Surface Aircraft Operational Status Messages by providing velocity and operational status information at the nominal update rate. Provide valid non-zero velocity data to the ADS-B System.

From an external source, input 95% accuracy figures of merit for horizontal velocity. Verify that for each horizontal velocity error value in Table 2-25 that the system generates ADS-B Surface Aircraft Operational Status Messages with the NAC_V subfield ("ME" bits 17 – 19, Message bits 49 – 51) set equal to the corresponding binary coding value shown for the NAC_V subfield in Table 2-25.

2.4.3.2.7.2.3.10 Verification of "UAT IN" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.10, §2.2.5.1.22)

Purpose/Introduction:

The "UAT IN" CC Code of the Aircraft Operational Status Messages (in ME bit 11, TYPE=31, Subtype=0, for airborne participants and in ME bit 16, TYPE=31, Subtype=1, for surface participants) is set to ONE in Aircraft Operational Status Messages if the transmitting aircraft IS fitted with a properly functioning Universal Access Transceiver (UAT) Receiving subsystem. Otherwise, this CC Code Subfield in Aircraft Operational Status Messages is set to ZERO (0) if there is NO capability in the aircraft to receive ADS-B UAT Messages.

Measurement Procedure:

Step 1: Verification of "UAT IN" CC Code Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide appropriate data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation IS fitted with a properly functioning ADS-B UAT Receiving Subsystem. Set the ADS-B Transmitting Subsystem to Airborne status. Verify that ME bit 11 is set to ONE (1).

Repeat this step while indicating that the aircraft has NO UAT IN Receive capability, and verify that ME bit 11 is set to ZERO (0).

Repeat this step again after setting the ADS-B Transmitting Subsystem to Surface status, and verify that ME bit 16 is set to ZERO (0).

Step 2: Verification of "UAT IN" CC Code – Data Lifetime

Set the ADS-B Transmitting Subsystem to Airborne status. Rerun the Test Procedure in Step 1. Remove the data source input for "UAT IN" CC Code information for a period of at least 5 seconds. Verify that ME bit 11 in the Aircraft Operational Status Message is set to a value of ZERO (0).

Set the ADS-B Transmitting Subsystem to Surface status. Rerun the Test Procedure in Step 1. Remove the data source input for "UAT IN" CC Code information for a period of at least 5 seconds. Verify that ME bit 16 in the Aircraft Operational Status Message is set to a value of ZERO (0).

2.4.3.2.7.2.3.11 Verification of "NIC Supplement-C" CC Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.3.11)

Appropriate test procedures required to validate the requirements of §2.2.3.2.7.2.3.11 are included in §2.4.3.2.7.2.6.

2.4.3.2.7.2.4 Verification of "OPERATIONAL MODE (OM)" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.4)

Appropriate test procedures required to validate the requirements of §2.2.3.2.7.2.4 are included in §2.4.3.2.7.2.4.1 through §2.4.3.2.7.2.4.4.

2.4.3.2.7.2.4.1 Verification of the "OM" Subfield Format Code in Aircraft Operational Status Messages (§2.2.3.2.7.2.4.1, §2.2.5.1.29)

Purpose/Introduction:

The first two bits of the OM subfield ("ME" bits 25 and 26) are reserved for selecting one of up to four OM subfield formats. For this version of these MOPS (RTCA DO-260A), the OM subfield format code is set to ZERO (binary 00).

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Verify that ME bits 25 and 26 are set to ZERO (binary 00).

2.4.3.2.7.2.4.2 Verification of the "TCAS/ACAS Resolution Advisory Active" OM Code Subfield in Aircraft Operational Status Message (§2.2.3.2.7.2.4.2, §2.2.5.1.30)

Purpose/Introduction:

The ADS-B Transmitting Subsystem sets the "TCAS/ACAS Resolution Advisory Active" (RA Active) Operational Mode Code to ZERO (0) as long as a TCAS II or ACAS Resolution Advisory is known **not** to be in effect (i.e., an update has been received within the last 2 seconds that indicates a "TCAS/ACAS Resolution Advisory is **not** Active"); otherwise, it sets this OM code to ONE (1).

Measurement Procedure:

Step 1: Verification of "RA Active" Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation DOES NOT have an active TCAS/ACAS Resolution Advisory in effect. Verify that ME bit 27 (Message bit 59) is set to ZERO (0)in the Aircraft Operational Status Messages.

Repeat this step while indicating that the installation DOES have an active TCAS/ACAS Resolution Advisory in effect. Verify that the "ME" bit 27 (Message bit 59) is set to ONE (1).

Step 2: Verification of "RA Active" OM Code – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for RA Active OM Code information for a period of at least 2 seconds. Verify that ME bit 27 in the Aircraft Operational Status Message is set to a value of ZERO (0).

2.4.3.2.7.2.4.3 Verification of the "IDENT Switch Active" OM Code Subfield in Aircraft Operational Status Message (§2.2.3.2.7.2.4.3, §2.2.5.1.31)

Purpose/Introduction:

The "IDENT Switch Active" Operational Mode code is a 1-bit subfield ("ME" bit 28, message bit 60) of the OM Code subfield in Aircraft Operational Status Messages. Initially, the "IDENT Switch Active" OM Code is set to ZERO (0). Upon activation of the IDENT switch, the ADS-B Transmitting Subsystem sets this code to ONE (1) for a period of 18 ±1 seconds. Thereafter, the ADS-B Transmitting Subsystem sets this OM Code to ZERO (0).

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide data externally at the interface to the ADS-B Transmitting Subsystem to indicate that the installation has an INACTIVE IDENT switch.

Verify that ME bit 28 (Message bit 60)is set to ZERO (0). Repeat this step while indicating that the installation has an ACTIVE IDENT switch. Verify that ME bit 28 (Message bit 60) is set to ONE (1). Allow 18 ±1 second to pass and verify that ME bit 28 (Message bit 60) has returned to a value of ZERO (0) in the next Aircraft Operational Status Message.

2.4.3.2.7.2.4.4 Verification of the bit Reserved for "Receiving ATC Services" OM Code Subfield in Aircraft Operational Status Message (§2.2.3.2.7.2.4.4)

Purpose/Introduction:

"ME" bit 29, Message bit 61 of the OM Code subfield in Aircraft Operational Status Messages **shall** be reserved for the "Receiving ATC Services" Operational Mode Code. If implemented into future versions of these MOPS, an ADS-B Transmitting Subsystem would set this OM Code to ONE when the ADS-B Transmitting Subsystem is Receiving ATC Services, as indicated by an update having been received via an appropriate interface on board the transmitting aircraft within the past 5 seconds. Otherwise, in this version of these MOPS, this OM Code bit **shall** be set to ZERO.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system simulating a message from an ADS-B Transmitting Subsystem. Verify that ME bit 29 is set to ZERO (0).

2.4.3.2.7.2.4.5 Verification of "Single Antenna Flag" OM Code Subfield in Aircraft Operational Status Message (§2.2.3.2.7.2.4.5, §2.2.5.1.49)

Purpose/Introduction:

The purpose of this test procedure is to verify that the ADS-B Transmit subsystem properly indicates the use of a Single Antenna in "ME" bit 30 (Message bit 62) in the OM Code of Aircraft Operational Status Messages.

Measurement Procedure:

Step 1: Non-Diversity Configuration

For ADS-B Transmitting Subsystems that operate with a single antenna, configure the system to broadcast Airborne Position Messages. Verify that the Single Antenna subfield is set to "ONE" (1) at all times in the Airborne Position Message.

Step 2: Diversity Configuration

For ADS-B Transmitting Subsystems that operate in the diversity mode, configure the system to broadcast Airborne Position Messages. Verify that the Single Antenna subfield is set to "ZERO" (0) at all times in the Airborne Position Message.

Disable one antenna channel by whatever means that the ADS-B Transmitting Subsystem utilizes to detect a non-functioning antenna channel. Verify that the Single Antenna subfield is set to "ONE" (1) in the Airborne Position Message. Repeat, except disable the alternate channel and verify that the Single Antenna subfield is set to ONE (1) in the Airborne Position Message.

2.4.3.2.7.2.4.6 Verification of "System Design Assurance" OM Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.4.6, §2.2.5.1.50)

Purpose/Introduction:

The "System Design Assurance" (SDA) subfield is a 2-bit ("ME" bits 31 – 32, Message bits 63 – 64) field that defines the failure condition that the ADS-B system is designed to support as defined in Table 2.2.3.2.7.2.4.6.

Measurement Procedure:

Step 1: Verification of "System Design Assurance" (SDA) OM Code Subfield

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide data externally at the interface to the ADS-B Transmit subsystem to establish each of the "System Design Assurance" (SDA) encoding defined in Table 2.2.3.2.7.2.4.6.

Verify that each "System Design Assurance" (SDA) parameter input condition that is identified in Table 2.2.3.2.7.2.4.6 that the system generates ADS-B Aircraft Operational Status Messages with the "System Design Assurance" (SDA) subfield set equal to the corresponding binary coding value indicated in Table 2.2.3.2.7.2.4.6.

Step 2: Verification of "System Design Assurance" (SDA) – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for "System Design Assurance" (SDA) information for a period of at least 5 seconds. Verify that the Aircraft Operational Status Messages are properly transmitted having the "System Design Assurance" (SDA) subfield ("ME" bits 31 and 32, Message bits 63 and 64) set to ZERO (0).

2.4.3.2.7.2.4.7 Verification of the "GPS Antenna Offset" OM Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.4.7)

Purpose/Introduction:

The "GPS Antenna Offset" subfield is an 8-bit ("ME" bits 33 – 40, Message bits 65 – 72) field in the OM Code Subfield of surface format Aircraft Operational Status Messages that defines the position of the GPS antenna.

Measurement Procedure:

➔ Blah Blah Blah ---- **NEED TEST PROCEDURE HERE** ZZZZZZZZZZZ ➔

2.4.3.2.7.2.4.8 Verification of the "Reserved" OM Code Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.4.8)

Purpose/Introduction:

"Reserved" bits, ("ME" bits 33 through 40, Message bits 65 through 72) in the OM Code Subfield of surface format Aircraft Operational Status Messages are reserved for future assignment. Until such future assignment, these bits shall be set to "ZERO" (0).

Measurement Procedure:

Step 1: Aircraft Operational Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with appropriate operational status data in order to initialize transmission of Aircraft Operational Status Messages.

Step 2: Verification of "Reserved" Bits

Verify that Aircraft Operational Status Messages are broadcast with "ME" bits 33 through 40 (Message bits 65 through 72) set to ZERO (0).

2.4.3.2.7.2.5 Verification of "ADS-B Version Number" Subfield in Aircraft Operational Status Message (§2.2.3.2.7.2.5)

Purpose/Introduction:

The "ADS-B Version Number" subfield is a 3-bit field (Message Bits 73 through 75, ME Bits 41 through 43) that is used to indicate the ADS-B Version Number of the ADS-B formats and protocols in use on the aircraft installation.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages at the nominal rate (see §2.2.3.3.2.6.2). Verify that the unit under test was built in conformance with RTCA DO-260B. Verify that the "Version Number" subfield in the Aircraft Operational Status Message is correctly set to binary 010 in Message Bits 73 through 75.

2.4.3.2.7.2.6 Verification of the "NIC Supplement-A" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.6)

Purpose/Introduction:

The NIC Supplement-A subfield in the Aircraft Operational Status Message is a 1-bit subfield ("ME" bit 44, Message bit 76) that, together with the TYPE subfield in Airborne Position and Surface Position Messages, is used to encode the Navigation Integrity Category (NIC) of the transmitting ADS-B participant.

Table 2-70 lists the possible NIC codes and the values of the TYPE Code subfield of the Airborne and Surface Position Messages, and the NIC Supplement subfield that is used to encode those NIC codes in messages on the 1090 MHz ADS-B data link.

Measurement Procedure:

Step 1: Verification of NIC Supplement Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system.

Verify that for each input NIC parameter that is specified by the R_C value in Table 2-70, that the system generates ADS-B Messages with the NIC Supplement-A subfield ("ME" bit 44) set equal to the corresponding binary coding value shown in Table 2-70. Do this for all TYPE Codes in Table 2-70 for both Airborne and Surface Position Messages.

Step 2: Verification of NIC Supplement-A – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for NIC Supplement-A for a period of at least 5 seconds. Verify that ME bit 44 in the Aircraft Operational Status Message is set to a value of ZERO (0).

2.4.3.2.7.2.7 Verification of the "Navigation Accuracy Category for Position (NAC_P)" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.7)

Purpose/Introduction:

The Navigation Accuracy Category for Position (NAC_P) is a 4-bit subfield of the ADS-B Aircraft Operational Status Message ("ME" bits 45 to 48, Message bits 77 to 80) that announces 95% accuracy limits for the horizontal position (and for some NAC_P values, the vertical position) that is being currently broadcast in airborne position and surface position messages. Table 2-71 specifies the accuracy limits for each NAC_P value.

Measurement Procedure:

Step 1: Verification of NAC_P Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system.

Verify that for each input NAC_P parameter that is specified by the EPU value in Table 2-71, that the system generates ADS-B Messages with the NAC_P subfield set equal to the corresponding binary coding value for the decimal value shown in Table 2-71.

Step 2: Verification of NAC_P – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for NAC_P for a period of at least 5 seconds. Verify that ME bits 45 to 48 in the Aircraft Operational Status Message are set to a value of ZERO (binary 0000).

2.4.3.2.7.2.8 Verification of the "Geometric Vertical Accuracy (GVA)" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.8)

Purpose/Introduction:

The "Geometric Vertical Accuracy (GVA)" subfield of Subtype=0 Aircraft Operational Status Message is a 2-bit field ("ME" bits 49-50, Message bits 81-82) defined in Table 2.2.3.2.7.2.8. The GVA field shall be set by using the Vertical Figure of Merit (VFOM) (95%) from the GNSS position source used to encode the geometric altitude field in the Airborne Position Message.

Measurement Procedure:

Step 1: Verification of GVA Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Set the Vertical Figure of Merit (VFOM) field to each of the following values in Table 2.4.3.2.7.2.8 and verify that the corresponding encoding is set in the GVAQ field of the Aircraft Operational Status Message.

Table 2.4.3.2.7.2.8: Geometric Vertical Accuracy Validation Values

Row	VFOM (meters)	GVA Encoding
1	Invalid	0
2	30.0	1
3	44.5	1
4	45.5	0
5	327.1	0

Step 2: Verification of GVA – Data Lifetime

Rerun Table 2.4.3.2.7.2.8, Row 2 from Step 1. Remove the data source input for GVA for a period of at least 2 seconds. Verify that the GVA subfield of the Aircraft Operational Status Message is set to ZERO (binary 00).

2.4.3.2.7.2.9 Verification of the "Source Integrity Level (SIL)" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.9)

Purpose/Introduction:

The Source Integrity Level (SIL) is a 2-bit subfield of "Subtype=0" ADS-B Aircraft Operational Status Messages ("ME" bits 51 and 52, Message bits 83 and 84) that defines the probability of the integrity containment region described by the NIC value being exceeded for the selected geometric position source, including any external signals used by the source. Table 2-72 defines the meaning of each SIL value. For installations where the SIL value is being dynamically updated, if an update has not been received from an on-board data source for SIL within the past 5 seconds, then the SIL subfield is set to a value of ZERO (0), indicating "Unknown."

Measurement Procedure:

Step 1: Verification of SIL Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system.

Verify that for each "SIL" parameter input condition that is specified by the probability of exceeding the R_C Integrity Containment Radius without detection (i.e., the values in Table 2-72), that the system generates ADS-B Messages with the "SIL" subfield set equal to the corresponding binary coding value shown in Table 2-72.

Step 2: Verification of SIL – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for SIL for a period of at least 5 seconds. Verify that ME bits 51 and 52 in the Aircraft Operational Status Message are set to a value of ZERO (binary 00).

2.4.3.2.7.2.10 Verification of the "Barometric Altitude Integrity Code (NIC_{BARO})" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.10)

Purpose/Introduction:

The "NIC_{BARO}" (Barometric Altitude Integrity Code) is a 1-bit subfield of "Subtype 0" ADS-B Aircraft Operational Status Messages ("ME" bit 53, Message bit 85) that is used to indicate whether or not the barometric pressure altitude being reported in the Airborne Position Message (§2.2.3.2.3) has been cross-checked against another source of pressure altitude. The "NIC_{BARO} " subfield is encoded in accordance with Table 2-73.

Measurement Procedure:

Step 1: Verification of NIC_{BARO} Transmission

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to the Airborne status.

Operationally select Barometric Pressure Altitude as the Primary Altitude information and verify that the "ALTITUDE TYPE" field in ME bit 10 of the Target State and Status Message is set to ZERO (0).

Input to the ADS-B Transmitting Subsystem the condition that signifies that the barometric pressure altitude has been crosschecked against another source of pressure altitude. Verify that the NIC_{BARO} field ME bit 53 of the Aircraft Operational Status Message is set to ONE (1).

Input to the ADS-B Transmitting Subsystem the condition that signifies that the barometric pressure altitude has NOT been crosschecked against another source of pressure altitude. Verify that the NIC_{BARO} field ME bit 53 of the Aircraft Operational Status Message is set to ZERO (0).

Step 2: Verification of NIC_{BARO} – Data Lifetime

Rerun the Test Procedure in Step 1. Remove the data source input for valid operational status information for a period of at least 5 seconds. Verify that ME bit 44 in the Target State and Status Message is set to a value of ZERO (0). Verify that the NIC_{BARO} field ME bit 53 of the Aircraft Operational Status Message is set to ZERO (0).

2.4.3.2.7.2.11 Verification of the "Aircraft/Vehicle Length and Width Code" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.11)

Purpose/Introduction:

The Aircraft/Vehicle (A/V) Length and Width Code Subfield is a 4-bit field ("ME" bits 21 to 24, Message bits 53 to 56) of the Aircraft Operational Status Messages (Subtype=1, for Surface Participants). This field describes the amount of space that an aircraft or ground vehicle occupies. The A/V Length and Width Code is based on the actual dimensions of the transmitting aircraft or surface vehicle as specified in Table 2-74. Once the actual Length and Width of the A/V has been determined, each A/V is assigned the smallest A/V Length and Width Code from Table 2-74 for which the actual length is less than or equal to the upper bound length for that Length/Width Code, and for which the actual width is less than or equal to the upper bound width for that Length/Width Code.

If the Aircraft or Vehicle is longer than 85 meters, or wider than 90 meters, then decimal Aircraft/Vehicle Length/Width Code 15 **shall** be used.

Measurement Procedure:

Step 1: Establish Initial Conditions

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid operational status information at the nominal update rate. Provide the A/V Length and Width Code data externally at the interface to the ADS-B system for an aircraft or vehicle greater than 25 meters in length and greater than 25 meters in width.

Set up the system to enable broadcast of ADS-B Aircraft Operational Status Messages with the air/ground status set to "On-Ground" according to the conditions defined in §2.2.3.2.1.2.

Step 2: Verification of Transmission of "A/V Length and Width Code" – ON GROUND

Verify that each of the A/V Length and Width Code values being transmitted by the ADS-B Transmitting Subsystem, are encoded according to Table 2-74 in ME bits 21 through 24 of the "A/V Length and Width Code" subfield. Verify that the Position Offset Applied (POA) in "ME" bit 11 (Message bit 43) is set to either ZERO (0) or ONE (1), based upon the input provided for the POA bit. Verify that the A/V Length and Width Code is accurately reflected in the next nroadcast of the Aircraft Operational Status Message.

Step 3: Verification of No Data Available

Set up the ADS-B Transmitting Subsystem as in Step 1 above, and then remove the data input for the A/V Length and Width Codes. Verify that the value being transmitted for the A/V Length and Width Code is set to ALL ZERO (binary 0000) in the next broadcast of the Aircraft Operational Status Message.

Step 4: Verification of Transmission of "A/V Length and Width Code" – AIRBORNE

Set up the system to enable broadcast of ADS-B Messages with the the air/ground status set to "Airborne" according to the conditions defined in §2.2.3.2.1.2. Verify that the Aircraft Operational Status Message is being broadcast with Subtype=0, and that the A/V Length and Width Code is not reflected in the next broadcast of the Aircraft Operational Status Message.

2.4.3.2.7.2.12 Verification of the "Track Angle/Heading" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.12, §2.2.5.1.38)

Purpose/Introduction:

The Track Angle/Heading subfield is a 1-bit field ("ME" bit 53, Message bit 85) of the ADS-B Aircraft Operational Status Message (Subtype=1, for Surface Participants) that allows correct interpretation of the data contained in the Heading/Ground Track subfield of the ADS-B Surface Position Message (§2.2.3.2.4) when the Air/Ground status is determined to be in the "On-Ground" state as defined in §2.2.3.2.1.2. The encoding of the Track Angle/Heading subfield is specified in Table 2-75.

Measurement Procedure:

Step 1: Verification of Track Angle Being Reported

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system and simulate data where the Track Angle is being reported. Set up the system to enable broadcast of ADS-B Messages at the nominal rate. Set the ADS-B Transmitting Subsystem to "On-Ground" status. Verify that "ME" bit 53 (Message bit 85) is set to ZERO (0).

Step 2: Verification of Heading Being Reported

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B Transmitting Subsystem and simulate data where the Heading is being reported. Set up the system to enable broadcast of ADS-B Messages at the nominal rate. Set the ADS-B Transmitting Subsystem to "On-Ground" status. Verify that ME bit 53 (Message bit 85) is set to ONE (1).

2.4.3.2.7.2.13 Verification of the "Horizontal Reference Direction (HRD)" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.13, §2.2.5.1.39)

Purpose/Introduction:

The Horizontal Reference Direction (HRD) subfield of the ADS-B Aircraft Operational Status Messages is a 1-bit field ("ME" bit 54, Message bit 86) that indicates the reference direction (true north or magnetic north) for horizontal directions such as heading, track angle. The Horizontal Reference Direction subfield is encoded as specified in Table 2-76.

Measurement Procedure:

Step 1: Verification of True North Being Reported

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system and simulate data where the (HRD) is True North. Verify that ME bit 54 (Message bit 86) is set to ZERO (0).

Step 2: Verification of Magnetic North Being Reported

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system and simulate data where the (HRD) is Magnetic North. Verify that ME bit 54 (Message bit 86) is set to ONE (1).

2.4.3.2.7.2.14 Verification of "SIL Supplement" Subfield in Aircraft Operational Status Messages (§2.2.3.2.7.2.14, §2.2.5.1.41)

Purpose/Introduction:

The "SIL Supplement" (Source Integrity Level Supplement) subfield is a 1-bit ("ME" bit 55, Message bit 87) field that defines whether the reported SIL probability is based on a "per hour" probability or a "per sample" probability as defined in Table 2-46. The purpose of the following procedure is th verify that the "SIL Supplement" sufield is being set appropriately.

Measurement Procedure:

Step 1: Aircraft Operation Status Message Initialization

Via the appropriate interface, provide the ADS-B Transmitting Subsystem with valid operational status data in order to initialize transmission of Aircraft Operational StatusMessages.

Step 2: Verification of SIL Supplement for "Per Hour" Probability

Via the appropriate data input interface, provide the ADS-B Transmitting Subsystem with valid data indicating that the integrity of the geometric position source is being established on a "Per Hour" basis.

Note: *If an actual interface is not used to provide "SIL Supplement" information, then ensure that a GNSS position source is being used to provide geometric positon data for the purpose of establishing position in the Airborne and Surface Position messages. (See section 2.2.5.1.42).*

Verify that the "SIL Supplement" subfield ("ME" bit 55, Message bit 87) in the Aircraft Operational Status Messages is set to "ZERO" (0).

Step 3: Verification of SIL Supplement for "Per Sample" Probability

Via the appropriate data input interface, provide the ADS-B Transmitting Subsystem with valid data indicating that the integrity of the geometric position source is being established on a "Per Sample" basis.

Note: *If an actual interface is not used to provide "SIL Supplement" information, then ensure that a Non-GNSS position source is being used to provide geometric positon data for the purpose of establishing position in the Airborne and Surface Position messages. (See section 2.2.5.1.42).*

Verify that the "SIL Supplement" subfield ("ME" bit 55, Message bit 87) in the Aircraft Operational Status Messages is set to "ONE" (1).

2.4.3.2.7.2.15 Verification of "Reserved" Subfields in Aircraft Operational Status Message (§2.2.3.2.7.2.15)

Purpose/Introduction:

There are two "Reserved" subfields in the Aircraft Operational Status Message. The first is a 2-bit field ("ME" bits 49 and 50, Message bits 81 and 82) of the Aircraft Operational Status Message (Subtype=1, for Surface Participants). The second "Reserved" subfield is a 1-bit field ("ME" bit 56, Message bit 88) that is reserved for future applications.

Measurement Procedure:

Step 1: Reserved field for Surface Participants

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Aircraft Operational Status Messages with Subtype=1, by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Verify that "ME" bits 49 and 50 (Message bits 81 and 82) are set to ALL ZEROs. Verify that "ME" bit 56 (Message bit 88) is set to ZERO (0).

Step 2: Reserved field of all Aircraft Operational Status Messages

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Aircraft Operational Status Messages, by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Verify that "ME" bit 56 (Message bit 88) is set to ZERO (0).

2.4.3.2.7.3 Verification of TYPE Code "23" ADS-B Messages for "TEST" (§2.2.3.2.7.3)

No specific test procedure is required to validate §2.2.3.2.7.3.

2.4.3.2.7.4 Verification of Surface System Status Messages with TYPE Code=24 (§2.2.3.2.7.4)

No specific test procedure is required to validate §2.2.3.2.7.4.

2.4.3.2.7.4.1 Verification of "TYPE" Code Subfield in Surface System Status Messages (§2.2.3.2.7.4.1)

No specific test procedure is required to validate §2.2.3.2.7.4.1.

2.4.3.2.7.4.2 Verification of "SUBTYPE" Code Subfield in Surface System Status Messages (§2.2.3.2.7.4.2)

No specific test procedure is required to validate §2.2.3.2.7.4.2.

2.4.3.2.7.4.3 Verification of "Surface System Status" Subfield in Surface System Status Messages (§2.2.3.2.7.4.3)

No specific test procedure is required to validate §2.2.3.2.7.4.3.

2.4.3.2.7.5 Verification of RESERVED TYPE Code "25" ADS-B Messages (§2.2.3.2.7.5)

No specific test procedure is required to validate §2.2.3.2.7.5.

2.4.3.2.7.6 Verification of RESERVED TYPE Code "26" ADS-B Messages (§2.2.3.2.7.6)

No specific test procedure is required to validate §2.2.3.2.7.6.

2.4.3.2.7.7 Verification of RESERVED TYPE Code "27" ADS-B Messages (§2.2.3.2.7.7)

No specific test procedure is required to validate §2.2.3.2.7.7.

2.4.3.2.7.8 Verification of Extended Squitter Aircraft Status Messages with TYPE Code=28 (§2.2.3.2.7.8)

2.4.3.2.7.8.1 Verification of Emergency/Priority Status and Mode A Code (Subtype=1) (§2.2.3.2.7.8.1)

2.4.3.2.7.8.1.1 Verification of "Emergency/Priority Status" Subfield in Aircraft Status Messages (§2.2.3.2.7.8.1.1)

Purpose/Introduction:

The Extended Squitter Aircraft Status Message (TYPE=28) is used to provide additional information regarding aircraft status. Subtype=1 is used specifically to provide the Emergency / Priority status and the broadcast of the Mode A Code.

Specific formatting of the TYPE=28, Subtype=1 Message is provided in Figure 2-13 and Appendix A, Figure A-8.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages. Set the ADS-B Transmitting Subsystem to Airborne status. Produce valid Airborne Position Messages at the nominal rate with valid position and altitude data with the Surveillance Status Subfield set to ONE (binary 01) to signify an emergency condition.

Verify that the ADS-B Transmitting Subsystem begins to transmit Extended Squitter Aircraft Status Messages at the nominal rate with the TYPE Subfield set to 28 (binary 1 1100) and the Subtype Subfield set to ONE (binary 001).

Verify that for each integer Emergency/Priority Status input value in Table 2.2.3.2.7.8.1.1 the system generates Extended Squitter Aircraft Status Messages with the TYPE subfield set to 28, the Subtype subfield set to ONE, and the Emergency/Priority Status subfield in each such message set equal to the corresponding binary coding in Table 2.2.3.2.7.8.1.1.

2.4.3.2.7.8.1.2 Verification of "Mode A (4096) Code" Subfield in Aircraft Status Messages (§2.2.3.2.7.8.1.2)

Purpose/Introduction:

The ADS-B Transmitting Subsystem will broadcast the Mode A (4096) Code setting in the Extended Squitter Aircraft Status Message (TYPE=28, Subtype=1).

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages. Set the ADS-B Transmitting Subsystem to Airborne status. Produce valid Airborne Position Messages at the nominal rate with valid position and altitude data. Verify that the ADS-B Transmitting Subsystem begins to transmit Extended Squitter Aircraft Status Messages at the nominal rate with the TYPE Subfield set to 28 (binary 1 1100) and the Subtype Subfield set to ONE (binary 001). Verify that the Mode A Code being broadcast is the one set by the pilot.

2.4.3.2.7.8.2 Verification of the 1090ES TCAS RA Message (Subtype = 2) (§2.2.3.2.7.8.2)

Purpose/Introduction:

The Extended Squitter Aircraft Status Message (TYPE=28, Subtype=2) is used to provide information regarding the TCAS Resolution Advisory (RA). Subtype=2 is used specifically to provide the encoding of this information as specified in Figure 2-14. The content of the fields of the 1090ES TCAS RA Message conform to the corresponding bits of transponder Register 30_{16} and are specified in ICAO Annex 10, Vol IV, §4.3.8.4.2.2.1.

Measurement Procedure:

Step 1: Broadcasting the 1090ES TCAS RA Broadcast Message (§2.2.3.2.7.8.2.a)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing data at the nominal rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged, ensuring that there is no "TCAS RA" indicated. Verify that the Aircraft Status Message is not being broadcast. Insert changed data into the ADS-B System to reflect a TCAS RA condition. Verify that the ADS-B System begins to transmit an Aircraft Status Message with Subtype=2 within 0.5 seconds after the transponder notification of the initiation of the TCAS RA. Verify that the ADS-B Transmitting Subsystem is broadcasting the Aircraft Status TCAS RA Broadcast Messages at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 2: Terminating the 1090ES Aircraft Status TCAS RA Broadcast Messages (§2.2.3.2.7.8.2.b)

Continue transmitting Aircraft Status Messages with Subtype=2 at the nominal rate. Verify that the system generates ADS-B Aircraft Status Messages with Subtype=2 with the appropriate subfields set equal to the corresponding binary coding values that are specified from the transponder according to ICAO Annex 10, Volume IV, §4.3.8.4.2.2.

Set the RA Termination flag in the transponder to ONE (1), and verify that the ADS-B System continues to transmit Aircraft Status Messages with Subtype=2 for not less than 10 seconds. Verify that 10 seconds after the RA Termination flag transitions from ZERO (0) to ONE (1) that the ADS-B System terminates broadcast of the Aircraft Status Messages with Subtype=2.

Step 3: Priority of the 1090ES Aircraft Status TCAS RA Broadcast Message (§2.2.3.2.7.8.2.c)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing data at the nominal rate. Provide the data externally at the interface to the ADS-B System. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged, ensuring that there is "No Emergency" indicated. Verify that the Aircraft Status Message is not being broadcast. Insert changed data into the ADS-B System indicating an emergency condition specified in Table 2-57. Verify that the system generates ADS-B Aircraft Status Messages with Subtype=1 with the "Emergency/Priority Status" subfield set equal to the corresponding binary coding value that was provided as input.

Continue transmitting Aircraft Status Messages with Subtype=1 at the nominal rate. Insert changed data into the ADS-B System to reflect a TCAS RA condition. Verify that the ADS-B System begins to transmit an Aircraft Status Message with Subtype=2 within 0.5 seconds after the transponder notification of the initiation of the TCAS RA. Verify that the ADS-B Transmitting Subsystem is broadcasting the Aircraft Status TCAS RA Broadcast Messages at a higher priority than the Aircraft Status Emergency/Priority Status Messages with Subtype=1.

2.4.3.2.7.9 Verification of RESERVED TYPE Code "30" ADS-B Messages (§2.2.3.2.7.9)

No specific test procedure is required to validate §2.2.3.2.7.9.

2.4.3.3 Verification of ADS-B Message Transmission Rates (§2.2.3.3)

No specific test procedure is required to validate §2.2.3.3.

Note: *One way to test for random uniformity is to use the Chi-squared Goodness-of-Fit test. It is not important to have a tight confidence (85% would suffice), but it is important to test both that the wait times are uniformly distributed and that the difference between consecutive wait times (modulo 400 μs) is uniformly distributed.*

2.4.3.3.1 Verification of Transmission Rates for Transponder - Based Transmitters (§2.2.3.3.1)

No specific test procedure is required to validate §2.2.3.3.1.

2.4.3.3.1.1 Verification of Transmission Rates Compliant with RTCA DO-181D (§2.2.3.3.1.1) (EUROCAE ED-73C)

Performance of ADS-B transmitters based on Mode S transponders **shall** validate Message Transmit Rates in accordance with RTCA DO-181D §2.5.4.6.2 (no applicable section in

EUROCAE ED-73C), for each class of transponder specified in the latest version of FAA TSO-C112.

2.4.3.3.1.2 Verification of Transmission Rates Not Specified in RTCA DO-181D (§2.2.3.3.1.2) (EUROCAE ED-73C)

When the transmission rate of a particular message type is not specified or is not tested in RTCA DO-181D (EUROCAE ED-73C), then the Mode S Transponder-Based ADS-B transmitters **shall** verify the message delivery performance for those messages in accordance with §2.4.3.3.2 through §2.4.3.3.2.12 of this document for Stand Alone Transmitters. If there is conflict between the requirements of RTCA DO-181D (EUROCAE ED-73C) and this document, then the requirements of RTCA DO-181D (EUROCAE ED-73C) **shall** be adhered to.

2.4.3.3.1.3 Verification of Maximum Transmission Rates for Transponder-Based Transmitters (§2.2.3.3.1.3)

Performance of ADS-B transmitters based on Mode S transponders **shall** validate maximum transmission rates in accordance with RTCA DO-181D (EUROCAE ED-73C), for each class of transponder specified in the latest version of FAA TSO-C112.

When the maximum transmission rate of a particular message type is not specified or is not tested in RTCA DO-181D (EUROCAE ED-73C), then the Mode S Transponder-Based ADS-B transmitters **shall** verify the maximum message delivery rate in accordance with §2.4.3.3.2.10 of this document for Stand Alone transmitters. If there is conflict between the requirements of RTCA DO-181D (EUROCAE ED-73C) and this document, then the requirements of RTCA DO-181D (EUROCAE ED-73C) **shall** be adhered to.

2.4.3.3.1.4 Verification of the ADS-B Periodic Status and Event-Driven Message Broadcast Rates (§2.2.3.3.1.4)

No specific test procedures are required to validate §2.2.3.3.1.4.

2.4.3.3.1.4.1 Verification of the ADS-B Target State and Status Message Broadcast Rates (§2.2.3.3.1.4.1)

Purpose/Introduction:

The Target State and Status Message(s) (TYPE=29, §2.2.3.2.7.1) is initiated only when the aircraft is airborne, and when vertical or horizontal target state information is available and valid as a minimum.

Measurement Procedure:

Step 1: No ADS-B Message Broadcasts - On-Ground (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Target State and Status Messages (TYPE=29, Subtype=ONE), including valid vertical target state information, valid horizontal target state information, and with the On-Ground condition, and verify that the

ADS-B Transmitting Subsystem is not broadcasting any ADS-B Target State and Status Messages.

Step 2: No ADS-B Message Broadcasts – With Neither Vertical Nor Horizontal Valid State Information (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

Change the status conditions to be invalid vertical target state information, invalid horizontal target state information, and with the Airborne condition, and verify that the ADS-B Transmitting Subsystem is not broadcasting any ADS-B Target State and Status Messages.

Step 3: ADS-B Message Broadcasts – With Only Vertical Valid State Information (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

Change the status conditions to be valid vertical target state information, invalid horizontal target state information, and with the Airborne condition, and verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds.

Step 4: ADS-B Message Broadcasts – With Only Horizontal Valid State Information (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

Change the status conditions to be invalid vertical target state information, valid horizontal target state information, and with the Airborne condition, and verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds.

2.4.3.3.1.4.2 Verification of the ADS-B Aircraft Operational Status Message Broadcast Rates (§2.2.3.3.1.4.2)

Purpose/Introduction:

The rates at which the Aircraft Operational Status Messages (TYPE=31 and Subtype=0, §2.2.3.2.7.2) are broadcast is specified in §2.2.3.3.1.4.2.

Measurement Procedure:

Step 1: ADS-B Message Broadcasts – ADS-B Target State and Status & Operational Status Messages (§2.2.3.3.1.4.2.a.ii)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of both Aircraft Operational Status Messages (TYPE=31, Subtype=ZERO), and ADS-B Target State and Status Messages (TYPE=29, Subtype=ONE), and verify that the ADS-B Transmitting Subsystem is broadcasting both ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds, and Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 2: ADS-B Message Broadcasts – ADS-B Target State and Status & Changes (§2.2.3.3.1.4.2.a.ii)

Separately initiate each of the four changes described in Condition 2 of §2.2.3.3.1.4.2, and for each separate case verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 3a: ADS-B Message Broadcasts – No ADS-B Target State and Status & With Changes (§2.2.3.3.1.4.2.b)

For each of the four cases decribed below, disable the tranmission of ADS-B Target State and Status Messages, and perform Steps 3a and 3b in sequence before proceeding to the next case.

Separately initiate each of the four changes described in Condition 2 of §2.2.3.3.1.4.2, and for each separate case verify that the ADS-B Transmitting Subsystem changes the Aircraft Operational Status Messages broadcast spacing to be uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 3b: ADS-B Message Broadcasts – No ADS-B Target State and Status & Following Changes (§2.2.3.3.1.4.2.a.i)

Before 23 seconds following the change for each separate case in Step 3a above, verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 3c: ADS-B Message Broadcasts – No ADS-B Target State and Status & Following Changes (§2.2.3.3.1.4.2.a.i)

After 25 seconds following the change for each separate case in Step 3a above, verify that the ADS-B Transmitting Subsystem reverts to broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 4: ADS-B Message Broadcasts in the “On-Ground” Condition – Repeat Tests With ADS-B Target State and Status & Operational Status Messages

Repeat the Step 1 setup, except replace the ADS-B Aircraft Operational Status Messages (TYPE=31, Subtype=ZERO) with ADS-B Aircraft Operational Status Messages (TYPE=31, Subtype=ONE), indicating an “On-Ground” condition, and then verify that the ADS-B Transmitting Subsystem is **not** broadcasting ADS-B Target State and Status Messages, and IS broadcastiung ADS-B Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 5: ADS-B Message Broadcasts in the "On-Ground" Condition – With Changes (§2.2.3.3.1.4.2)

Separately initiate each of the two (2) changes described in §2.2.3.3.1.4.2, Condition 2 "c" and "d," and for each separate case, verify that the ADS-B Transmitting Subsystem continues broadcasting ADS-B Operational Status Messages with Subtype=ONE, at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

2.4.3.3.1.4.3 Verification of the "Extended Squitter Aircraft Status" ADS-B Event-Driven Message Broadcast Rate (§2.2.3.3.1.4.3)

Appropriate test procedures to verify the broadcast rates of the Extended Squitter Aircraft Status Messages are included in §2.4.3.3.1.4.3.1 through §2.4.3.3.1.4.3.2.

2.4.3.3.1.4.3.1 Verification of "Emergency/Priority Status Message" Broadcast Rates

Purpose/Introduction:

The rate at which the "Extended Squitter Aircraft Status Message" (TYPE=28), (see §2.2.3.2.7.8) is broadcast using the Event-Driven protocol, varies depending on ➔ ZZZZZZZZZZZ ➔

Measurement Procedure:

Step 1: ADS-B ➔ ZZZZZZZZZZZ ➔

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Extended Squitter Aircraft Status Messages with Emergency/Priority Status (TYPE=28, Subtype=1), ➔ **ZZZZZZZZZZZ IT MAY BE MORE APPROPRIATE TO MOVE SOME OF THE FOLLOWING TEST STEPS TO THE FOLLOWING SUBPARAGRAPHS AFTER INSPECTION ZZZZZZZZZZZ** ➔

Step 2: ADS-B ➔ **ZZZZZZZZZZZ** ➔

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Extended Squitter Aircraft Status Messages with Emergency/Priority Status (TYPE=28, Subtype=1), ➔ **ZZZZZZZZZZZ** ➔

Step 3: ADS-B Message Broadcasts – Emergency Status Termination

Terminate the Emergency State condition, and verify that the ADS-B Transmitting Subsystem ceases broadcasting of the Extended Squitter Aircraft Status Emergency/Priority Status Messages.

Step 4: ADS-B Message Broadcasts – TCAS RA Broadcast

Provide the ADS-B Transmitting Subsystem with valid TCAS RA data necessary for the generation of ADS-B Extended Squitter Aircraft Status TCAS RA

Broadcast Messages, and verify that the ADS-B Transmitting Subsystem is broadcasting Extended Squitter Aircraft Status TCAS RA Broadcast Messages (TYPE=28, Subtype=2) at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 5: ADS-B Message Broadcasts – Termination of TCAS RA Broadcast

Terminate the TCAS RA condition, and verify that the ADS-B Transmitting Subsystem ceases broadcasting of the Extended Squitter Aircraft Status TCAS RA Broadcast Messages not less than 24 seconds after the RA Termination flag transitions from ZERO (0) to ONE (1) (§2.2.3.2.7.8.2).

2.4.3.3.1.4.3.1.1 Verification of "Emergency/Priority Status Message" Broadcast Rates When Transmission of Mode A Code is Disabled (§2.2.3.3.1.4.3.1.1)

Purpose/Introduction:

➔ ZZZZZZZZZZZ ZZZZZZZZZZZ ZZZZZZZZZZZ ➔

Measurement Procedure:

➔ ZZZZZZZZZZZ ZZZZZZZZZZZ ZZZZZZZZZZZ ➔

2.4.3.3.1.4.3.1.2 Verification of "Emergency/Priority Status Message" Broadcast Rates When Transmission of Mode A Code is Enabled (§2.2.3.3.1.4.3.1.2)

Purpose/Introduction:

➔ ZZZZZZZZZZZ ZZZZZZZZZZZ ZZZZZZZZZZZ ➔

Measurement Procedure:

➔ ZZZZZZZZZZZ ZZZZZZZZZZZ ZZZZZZZZZZZ ➔

2.4.3.3.1.4.3.2 Verification of "TCAS RA Broadcast Message" Broadcast Rate (§2.2.3.3.1.4.3.2)

Purpose/Introduction:

➔ ZZZZZZZZZZZ ZZZZZZZZZZZ ZZZZZZZZZZZ ➔

Measurement Procedure:

➔ ZZZZZZZZZZZ ZZZZZZZZZZZ ZZZZZZZZZZZ ➔

2.4.3.3.1.4.4 Verification of the "TYPE Code=23 (TEST)" ADS-B Event-Driven Message Broadcast Rate (§2.2.3.3.1.4.4)

Purpose/Introduction:

The ADS-B Event-Driven "TEST" Messages with Subtype=0 is broadcast NOT MORE THAN ONCE each time the Event-Driven Test Information is updated to the transponder.

Measurement Procedure:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B broadcast messages for display on an oscilloscope. Update the ADS-B Event-Driven "TEST" Message and verify that it is broadcast only once. Repeat 10 times.

2.4.3.3.1.4.5 Verification of the "TYPE Codes 24 – 27" and "TYPE Code=30" ADS-B Event-Driven Message Broadcast Rate (§2.2.3.3.1.4.5)

Purpose/Introduction:

In general, TYPE Codes 24 - 27 and TYPE Code=30 ADS-B Event-Driven Messages are broadcast ONCE each time the Event-Driven TYPE Codes 24 - 27 or TYPE Code=30 information is updated to the transponder.

Measurement Procedure:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B broadcast messages for display on an oscilloscope.

These messages are reserved for future expansion. When implemented, perform the following test:

Update each of the implemented TYPE Codes 24 through 27, or TYPE Code=30 ADS-B Event-Driven Messages in turn and verify that it is broadcast only once. Repeat 10 times.

2.4.3.3.1.4.6 Verification of the ADS-B Message Transmission Scheduing (§2.2.3.3.1.4.6)

Appropriate test procedures required to validate the requirements of §2.2.3.3.1.4.6 are included in §2.2.3.3.1.4.6.1.

2.4.3.3.1.4.6.1 Verification of the Event-Driven Message Scheduling Function (§2.2.3.3.1.4.6.1)

Purpose/Introduction:

The Event-Driven Message Scheduling Function ensures that the total Event-Driven message rate does not exceed 2 transmitted messages per second. This is consistent with the required overall maximum allowed transmission rate specified in §2.2.3.3.1.3. The requirements for the rules of prioritizing the Event-Driven Message transmissions and limiting the transmission rates are specified in §2.2.3.3.1.4.6.1. The broadcast rates for all 1090ES ADS-B Messages are summarized in Table 2-77.

Measurement Procedure:

The Measurement Procedures include the broadcast of the baseline Airborne Position, Airborne Velocity and Aircraft ID & Category Messages at their specified nominal rates (i.e, at combined nominal rate of 4.2 messages per second). The Measurement Procedure would then define a specific timed sequence of 'events' that would result in the generation of a specific sequence of ADS-B Event-Driven Messages that is known to exceed the nominal broadcast limit of 2 messages per second that is allocated for Event-Driven Messages. The intent of this procedure is to cause the development of a queue of pending ADS-B Event-Driven Messages. In order to "load up" the Event-Driven Message queue it is suggested to use the Event-Driven Messages specified in Table 2-145.

Table 2-145: Event-Driven Messages to Test the Scheduling Function

Message	Message TYPE and Subtype Codes	Message Priority Level
Extended Squitter Aircraft Status (TCAS RA Broadcast)	TYPE=28 and Subtype=1	1
Extended Squitter Aircraft Status (Emergency/Priority and Mode A Code)	TYPE=28 and Subtype=1	2

It is necessary to inject data that would result in the Event-Driven Messages identified in Table 2-145 being generated under the following test scenario. The test procedures **shall** consist of the following steps performed as a continuous sequence of events. Commencing with Step 2 below, it is expected that a pending ADS-B Message queue will develop that must be managed by the ADS-B Message Scheduling Function.

Step 1: Place the ADS-B system in a test mode in which Test Messages (i.e., TYPE=23) are generated at a nominal rate of 2 per second.

Verify: a) Test Messages are broadcast (see §2.2.3.3.1.4.4) at a nominal rate of 2 per second over a 30 second test period.

b) A nominal total broadcast rate of ≤ 6.2 messages per second over the 30 second test period as in (a) above.

Step 2: With the ADS-B still in a test mode, as defined in Step 1 in which Test Messages are being generated, inject Operational Status Message data and refresh at least once per 0.5 second with no change in data contents.

Verify: a) Aircraft Operational Status Messages are broadcast at nominal intervals of 0.8 seconds (see §2.2.3.3.1.4.2) over a 23 second test period.

b) Aircraft Operational Status Messages are broadcast at nominal intervals of 2.5 seconds after 25 seconds with no change in the input data, verified over a 30 second test period (i.e., the test period starts 2 seconds after the end of (a) above and continues for 30 seconds).

c) Test Messages are broadcast at nominal intervals of 1.25 seconds over the same 23 second test period as (a) above and at nominal intervals of 0.625 seconds over the subsequent 32 second test period (i.e., ending coincident with the end of (b) above) and such that the nominal total Event-Driven Message broadcast rate is a nominal 2 messages per second.

d) A nominal total broadcast rate of ≤ 6.2 messages per second over a 55 second test period.

Step 3: With the ADS-B still in a test mode, as defined in Step 2 in which Test Messages and Aircraft Operational Status Messages are being generated, also inject Target State and Status data and refresh at least once per 0.5 second.

Verify: a) Target State and Status Messages are broadcast at nominal intervals of 1.25 seconds over a 30 second test period (see §2.2.3.3.1.4.1).

b) Aircraft Operational Status Messages are broadcast at nominal intervals of 2.5 seconds verified over the same 30 second test period as (a).

c) Test Messages are broadcast at nominal intervals of 1.25 seconds over the same 23 second test period as (a) above and at nominal intervals of 1.25 seconds over the same test period as (a) and (b) above (i.e., such that the nominal total Event-Driven Message broadcast rate for Event-Driven Messages is 2 per second).

d) A nominal total broadcast rate of 6.2 messages per second is not exceeded over the same 30 second test period as (a), (b) and (c) above.

Step 4: With the ADS-B system still in a test mode, as defined in Step 3, in which Test, Aircraft Operational Status, and Target State and Status Messages are being generated, inject Extended Squitter Aircraft Status Message data, and refresh at least once per 1.0 second with no change in data contents.

Verify:
a) Extended Squitter Aircraft Status Messages (TYPE=28, Subtype=1) are broadcast at nominal intervals of 2.5 seconds (see §2.2.3.3.1.4.3) over a 30 second test period.
b) Target State and Status Messages are broadcast at nominal intervals of 1.25 seconds over the same 30 second test period as (a).
c) Aircraft Operational Status Messages are broadcast at nominal intervals of 2.5 seconds verified over the same 30 second test period as (a) and (b).
d) Test Messages are broadcast at nominal intervals of 5 seconds over the same 30 second test period as (a), (b) and (c) above.
e) A nominal total broadcast rate of 6.2 messages per second is not exceeded over the same 30 second test period as (a), (b), (c) and (d).

2.4.3.3.2 Verification of Transmission Rates for Stand Alone Transmitters (§2.2.3.3.2)

Purpose/Introduction:

Stand Alone Transmitters for Class A0 and Class B0 equipment are those implemented independent of a Mode S transponder. Such transmitters must meet the transmission rate requirements of §2.2.3.3.1.3 and the message update rate requirements specified in §2.2.3.3.2 and its subparagraphs. Extended Squitter messages must be transmitted at random intervals that are uniformly distributed over the specified time interval using a time quantization no greater than 15 milliseconds.

Equipment Required:

A Method of loading valid data for the generation of ADS-B Airborne Position, Surface Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status broadcast messages into the ADS-B Transmitting Subsystem under test.

A Method of recording and time stamping all ADS-B Broadcast messages transmitted by the ADS-B Transmitting Subsystem under test with the time stamping quantization being 15 milliseconds or less.

Measurement Procedure:

Step 1: ADS-B Message Broadcast Setup

Provide the ADS-B Transmitting Subsystem under test with all valid necessary data for the generation of ADS-B Airborne Position, Aircraft Identification and

Category, Airborne Velocity, Target State and Status, and Operational Status broadcast messages.

Verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Messages.

Step 2: ADS-B Message Recording and Time Stamping

Record and time stamp all ADS-B Messages that are broadcast by the ADS-B Transmitting Subsystem for a period of not less than 10 minutes.

Note: *At a maximum rate of 6.2 ADS-B Broadcast messages per second, the recording period of 10 minutes should provide approximately 3,720 messages. That is, approximately 1,200 Airborne Position, 1,200 Airborne Velocity, 480 Target State and Status, 240 Operational Status, 120 Aircraft Identification and Category Messages, and up to 480 other On-Condition Messages. This should provide a representative sample size to support the subsequent statistical evaluations.*

Step 3: Uniform Distribution Checks

For each of the ADS-B Airborne Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status Message types transmitted, verify that the messages were uniformly and randomly distributed over the specified range of transmission intervals for each particular message type.

Step 4: Interval Quantization Checks

For each of the ADS-B Airborne Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, and Operational Status Message types transmitted, verify that the messages were distributed with the jitter spacing being 15 milliseconds or less between messages of equivalent type.

Step 5: Surface Condition checks (High Rate)

Repeat steps 1 -through- 4 using only ADS-B Surface Position and Aircraft Identification and Category Messages using the high transmission rate (see §2.2.3.3.2.3 and §2.2.3.3.2.4) for each message type.

Step 6: Surface Condition checks (Low Rate)

Repeat steps 1 -through- 4 using only ADS-B Surface Position and Aircraft Identification and Category messages using the low transmission rate (see §2.2.3.3.2.3 and §2.2.3.3.2.4) for each message type.

2.4.3.3.2.1 Verification of Power-On Initialization and Start Up (§2.2.3.3.2.1)

No specific test procedure is required to validate §2.2.3.3.2.1.

2.4.3.3.2.1.1 Verification of Power-On Initialization (§2.2.3.3.2.1.1)

Equipment Required

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure

Step 1: No Data Available (§2.2.3.3.2.1.1.a)

Ensure that no appropriate valid message data are available for any of the possible ADS-B broadcast messages. Power up the equipment. Verify that no transmissions occur.

Step 2: Valid Data available (§2.2.3.3.2.1.1.b)

For each ADS-B Position and Velocity Message type in turn, ensure that appropriate valid ADS-B Message data are available for that message type only. Power up the equipment. Verify that the correct ADS-B broadcast message is transmitted starting no later than 2.0 seconds after Power-On.

Step 3: Built-in-Test Completion (§2.2.3.3.2.1.1.c)

a. Repeat the procedure provided in Step 2

b. Verify that the Unit-Under-Test (UUT) has completed all Built-in-Test functions no later than 20 seconds after applying power to the UUT.

Note: *In order to demonstrate compliance with this procedure, the manufacturer should design the equipment to provide an appropriate indication that the equipment is performing Built-in-Test functions during the Power Up sequence.*

2.4.3.3.2.1.2 Verification of Start Up (§2.2.3.3.2.1.2)

Note: *To save time and repeating of tests the tests in this section can be combined with those testing §2.2.3.3.2.2 to §2.2.3.3.2.9 inclusive.*

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: Data Available for only One Variable Data Field (§2.2.3.3.2.1.2.a and b)

Ensure that no appropriate valid message data are available for any of the possible ADS-B broadcast messages. Power up the equipment. Verify that no transmissions occur. For ADS-B broadcast message specified in §2.2.3.3.2.2, for each data field in turn, make data available for only that data field. Verify that for each data field, the message is transmitted at the rate specified in §2.2.3.3.2.3 to §2.2.3.3.2.9 inclusive.

Repeat Step 1 for all of the ADS-B broadcast message types specified in §2.2.3.3.2.3 to §2.2.3.3.2.9 inclusive.

Step 2: Data Ceases to be Available After Transmission has been Initiated (§2.2.3.3.2.1.2.c)

Ensure that appropriate valid ADS-B Message data are available for each ADS-B Message type. For each ADS-B Message type in turn, make all data fields unavailable and verify that the broadcast of the relevant message is discontinued when the input data has not been available for a period as specified in §2.2.3.3.2.12.

2.4.3.3.2.2 Verification of ADS-B Airborne Position Message Broadcast Rate (§2.2.3.3.2.2)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope, or equivalent method of observing the message content.

Measurement Procedure:

Step 1: All Data Available (§2.2.3.3.2.2)

Ensure that the equipment is set to the "Airborne" condition and that the appropriate valid ADS-B Airborne Position data is available. Verify that the ADS-B Airborne Position Message is broadcast at intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.2.

Step 2: Only Barometric Altitude Data Available (§2.2.3.2.3.1.3.1)

Repeat Step 1 with only barometric altitude data available this time and verifying that the TYPE Code = 0.

Step 3: Data Ceases to be Updated (§2.2.3.3.2.11a)

Establish the broadcast of the ADS-B Airborne Position Message as in Step 1 above. Then stop the input of data (no position and no altitude) for the ADS-B Airborne Position Message.

Verify that the ADS-B Airborne Position Message is broadcast with all data bits being set to ZERO 2.0 seconds after stopping the data input.

Verify that the ADS-B Airborne Position Message is no longer broadcast 60 ±1 seconds after stopping the data input.

2.4.3.3.2.3 Verification of ADS-B Surface Position Message Broadcast Rate (§2.2.3.3.2.3)

Equipment Required:

Provide a method of loading valid data for broadcasting ADS-B Messages into the ADS-B equipment under test. Provide a method of monitoring the transmitted ADS-B Messages and measuring the rate at which they are output.

Measurement Procedure:

Step 1: Switching from High Rate to Low Rate & Data Ceases to be Updated (§2.2.3.3.2.3.a(1) and c & §2.2.3.3.2.12)

Ensure that the equipment is set to the "On the Ground" condition and that the appropriate valid ADS-B Surface Position data is provided such that the position is changing at a rate of 10.1 meters in any 30 second interval. At least 61 seconds after the start of the data input, verify that the ADS-B Surface Position Message is broadcast at intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.3.b.

Input new ADS-B Surface Position data with the position data changing at a rate of 9.9 meters in any 30 second interval. At least 61 seconds after the inputting of the new data, verify that the ADS-B Surface Position Message is broadcast at intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds as specified in §2.2.3.3.2.3.c.

Stop the input of data, and for Transponder-Based systems verify that the ADS-B Surface Position Messages are no longer broadcast 60 ±1 seconds after the data becomes unavailable. For Non-Transponder-Based systems verify that TYPE Code of ZERO is output at the "High" transmission rate after 2 seconds. Monitor for 120 seconds and verify that TYPE Code of ZERO continues to be broadcast.

Step 2: Switching from Low Rate to High Rate & Data Ceases to be Updated (§2.2.3.3.2.3.a(2) and c & §2.2.3.3.2.12)

Ensure that the equipment is set to the "On the Ground" condition and that the appropriate valid ADS-B Surface Position data is provided such that the position is stationary. At least 61 seconds after establishing the data, verify that the ADS-

B Surface Position Messages are broadcast at intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds as specified in §2.2.3.3.2.3.c.

Input new ADS-B Surface Position data such that the position is stationary and 10.1 meters away from the position above. One (1) second after inputting the new data, verify that the ADS-B Surface Position Messages are broadcast at intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.3.b. Also verify that at least 61 seconds after establishing the new data that the ADS-B Surface Position Message is broadcast at intervals that are uniformly distributed over the range 4.8 to 5.2 seconds as specified in §2.2.3.3.2.3.c.

Stop the input of data, and for Transponder-Based systems verify that the ADS-B Surface Position Messages are no longer broadcast 60 ±1 seconds after the data becomes unavailable. For Non-Transponder-Based systems verify that TYPE Code of ZERO is output at the "High" transmission rate after 2 seconds. Monitor for 120 seconds and verify that TYPE Code of ZERO continues to be broadcast.

2.4.3.3.2.4 Verification of ADS-B Aircraft Identification and Category Message Broadcast Rate (§2.2.3.3.2.4)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: Airborne with No Target State, and Aircraft Operational Status (§2.2.3.3.2.4.a)

Ensure that the equipment is set to the "Airborne" condition and that the appropriate valid ADS-B Aircraft Identification and Category data is available. Verify that the ADS-B Aircraft Identification and Category Message is broadcast at intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds as specified in §2.2.3.3.2.4.a.

Step 2: Airborne with Target State, and Aircraft Operational Status (§2.2.3.3.2.4.b)

Ensure that the equipment is set to the "Airborne" condition and that the appropriate valid ADS-B Aircraft Identification and Category data is available.

Provide the equipment with valid Target State Data necessary to establish Target State and Status Broadcast Messages (see §2.2.3.2.7.1 and §2.2.3.3.2.6.1).

Provide the equipment with valid Target State Data necessary to establish Target State and Status Broadcast Messages (see §2.2.3.2.7.1 and §2.2.3.3.2.6.1).

Provide the equipment with valid Operational Status Data necessary to establish Aircraft Operational Status Messages (see §2.2.3.2.7.2 and §2.2.3.3.2.6.2).

Verify that Target State and Status, and Aircraft Operational Status Messages are being broadcast.

Note: *It is not necessary to verify the rate of broadcast for the Intent Messages at this time since direct verification of the broadcast rates for these messages is verified in procedures later in this document.*

Verify that the ADS-B Aircraft Identification and Category Message is broadcast at an average rate of one message per 5 seconds over a time period of 60 seconds.

Step 3: On the Ground (§2.2.3.3.2.4.c)

Ensure that the equipment is set to the "On the Ground" condition and that the appropriate valid ADS-B Aircraft Identification and Category data is available. Verify that the ADS-B Aircraft Identification and Category Message is broadcast at intervals that are uniformly distributed over the range of 9.8 to 10.2 seconds as specified in §2.2.3.3.2.4.c.

Step 4: Data Ceases to be Updated (§2.2.3.3.2.11)

Establish the broadcast of the ADS-B Aircraft Identification and Category Message as in Step 1 above. Then stop the input of data for the ADS-B Aircraft Identification and Category Message.

Verify that the ADS-B Aircraft Identification and Category Message continues to be broadcast with the same data that existed prior to stopping the data input for at least 61 seconds after stopping the data input.

2.4.3.3.2.5 Verification of ADS-B Velocity Information Message Broadcast Rate (§2.2.3.3.2.5)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: Data Available (§2.2.3.3.2.5)

Ensure that the appropriate valid ADS-B Velocity Information data is available. Verify that the ADS-B Velocity Information message is broadcast at intervals that are uniformly distributed over the range of 0.4 to 0.6 seconds as specified in §2.2.3.3.2.5.a.

Step 2: Data Ceases to be Updated (§2.2.3.3.2.11)

Establish the broadcast of the ADS-B Airborne Velocity Message as in Step 1 above. Then stop the input of data for the ADS-B Airborne Velocity Message, except for the Intent Change Flag.

Verify that the ADS-B Airborne Velocity Message is not broadcast 2.6 seconds after stopping the data input.

2.4.3.3.2.6 Verification of ADS-B Periodic Status Message Broadcast Rates (§2.2.3.3.2.6)

No specific test procedure is required to validate §2.2.3.3.2.6.

2.4.3.3.2.6.1 Verification of ADS-B Target State and Status Message Broadcast Rates (§2.2.3.3.2.6.1)

Purpose/Introduction:

The requirements of §2.2.3.3.1.4.1 are applicable. The Target State and Status Messages (TYPE=29, Subtype=0, §2.2.3.2.7.1) are broadcast at random intervals that are uniformly distributed over the range of 1.2 to 1.3 seconds relative to the previous Target State and Status Message for as long as data is available to satisfy the requirements of §2.2.3.3.1.4.1. Exceptions to these transmission rate requirements are specified in §2.2.3.3.2.9.

Equipment Required:

Provide a Method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: No ADS-B Message Broadcasts - On-Ground (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

If the ADS-B Transmitting Subsystem under test cannot be placed in the On-Ground condition, proceed to Step 2.

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Target State and Status Messages (TYPE=29, Subtype=ZERO), impose an On-Ground condition, and verify that the ADS-B Transmitting Subsystem is not broadcasting any ADS-B Target State and Status Messages.

Step 2: No ADS-B Message Broadcasts – Without Either Vertical or Horizontal Valid State Information (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

If the ADS-B Transmitting Subsystem under test cannot be placed in all of the following conditions, proceed to Step 3.

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Target State and Status Messages (TYPE=29, Subtype=ZERO), impose invalid vertical target state information, invalid horizontal Target State information, and set to the Airborne condition, and verify that the ADS-B Transmitting Subsystem is not broadcasting any ADS-B Target State and Status Messages.

Step 3: ADS-B Message Broadcasts – With Only Vertical Valid State Information (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

If the ADS-B Transmitting Subsystem under test cannot be placed in all of the following conditions, proceed to Step 4.

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Target State and Status Messages (TYPE=29, Subtype=ZERO), impose valid vertical Target State information, invalid horizontal target state information, and set to the Airborne condition, and verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds.

Step 4: ADS-B Message Broadcasts – With Only Horizontal Valid State Information (§2.2.3.3.1.4.1.a & §2.2.3.3.1.4.1.b)

If the ADS-B Transmitting Subsystem under test cannot be placed in all of the following conditions, proceed to Step 5.

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Target State and Status Messages (TYPE=29, Subtype=ZERO), impose invalid vertical target state information, valid horizontal target state information, and set to the Airborne condition, and verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds.

Step 5: Mutual Suppression Exception (§2.2.3.3.2.9)

If the Mutual Suppression Interface is provided, force the Mutual Suppression condition at a time, and for a duration, which insures that the next expected ADS-B Target State and Status Message will be delayed, and verify that the ADS-B Target State and Status Message is delayed.

Remove the Mutual Suppression condition, and verify that ADS-B Target State and Status Messages resume broadcasting at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds.

Step 6: ADS-B Message Broadcast Sixty Second Timeout – ADS-B Target State and Status Messages (§2.2.3.3.2.11c & §2.2.3.3.2.12)

Interrupt the changing of the input data necessary for transmission of ADS-B Target State and Status Messages (TYPE=29, Subtype=0) with new (valid) data, and after 60 seconds verify that the unchanged data fields are NOT cleared to ZERO.

Stop the input of data, and verify that the ADS-B Target State and Status Messages (TYPE=29, Subtype=0) are no longer broadcast 60 ±1 seconds after the data becomes unavailable.

2.4.3.3.2.6.2 Verification of ADS-B Aircraft Operational Status Message Broadcast Rates (§2.2.3.3.2.6.2)

Purpose/Introduction:

The Aircraft Operational Status Messages (TYPE=31 and Subtype=0) (§2.2.3.2.7.2) are broadcast at varying rates as specified in §2.2.3.3.1.4.2. Exceptions to these transmission rate requirements are specified in §2.2.3.3.2.9.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: ADS-B Message Broadcasts – ADS-B Target State and Status & Operational Status Messages (§2.2.3.3.1.4.2.a.ii)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of both Aircraft Operational Status Messages (TYPE=31, Subtype=ZERO), and ADS-B Target State and Status Messages (TYPE=29, Subtype=ZERO), and verify that the ADS-B Transmitting Subsystem is broadcasting both ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds, and Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 2: ADS-B Message Broadcasts – ADS-B Target State and Status & Changes (§2.2.3.3.1.4.2.a.ii)

Separately initiate each of the four changes described in Condition 2 (§2.2.3.3.1.4.2), and for each separate case verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 3a: ADS-B Message Broadcasts – No ADS-B Target State and Status & With Changes (§2.2.3.3.1.4.2.b)

For each of the four cases decribed below, disable the tranmission of ADS-B Target State and Status Messages, and perform Steps 3a and 3b in sequence before proceeding to the next case.

Separately initiate each of the four changes described in Condition 2 (§2.2.3.3.1.4.2), and for each separate case verify that the ADS-B Transmitting Subsystem changes the Aircraft Operational Status Messages broadcast spacing to be uniformly distributed over the range of 0.75 to 0.85 seconds.

<u>Step 3b:</u> <u>ADS-B Message Broadcasts – No ADS-B Target State and Status & Following Changes (§2.2.3.3.1.4.2.a.i)</u>

Before 23 seconds following the change for each separate case in Step 3a above, verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

<u>Step 3c:</u> <u>ADS-B Message Broadcasts – No ADS-B Target State and Status & Following Changes (§2.2.3.3.1.4.2.a.i)</u>

After 25 seconds following the change for each separate case in Step 3a above, verify that the ADS-B Transmitting Subsystem reverts to broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

<u>Step 4:</u> <u>Mutual Suppression Exception (§2.2.3.3.2.9)</u>

If the Mutual Suppression Interface is provided, force the Mutual Suppression condition at a time, and for a duration, which insures that the next expected Aircraft Operational Status Message will be delayed, and verify that the Aircraft Operational Status Message is delayed.

Remove the Mutual Suppression condition, and verify that Aircraft Operational Status Messages resume at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

<u>Step 5:</u> <u>ADS-B Message Broadcasts – Repeat Tests With ADS-B Target State and Status & Operational Status Messages</u>

Repeat the Step 1 setup, except replace the Aircraft Operational Status Messages (TYPE=31, Subtype=0) with Aircraft Operational Status Messages (TYPE=31, Subtype=1), verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds, and Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

<u>Step 6:</u> <u>ADS-B Message Broadcasts – ADS-B Target State and Status & Changes (§2.2.3.3.1.4.2.c)</u>

Separately initiate each of the four changes described in Condition 2 (§2.2.3.3.1.4.2), and for each separate case verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

<u>Step 7a:</u> <u>ADS-B Message Broadcasts – No ADS-B Target State and Status & With Changes (§2.2.3.3.1.4.2.c)</u>

For each of the four cases described below, disable the transmission of ADS-B Target State and Status Messages, and perform Steps 7a, 7b, and 7c in sequence before proceeding to the next case.

Separately initiate each of the four changes described in Condition 2 (§2.2.3.3.1.4.2), and for each separate case verify that the ADS-B Transmitting Subsystem continues to broadcast the Aircraft Operational Status Messages at a spacing which is uniformly distributed over the range of 4.8 to 5.2 seconds.

Step 7b: ADS-B Message Broadcasts – No ADS-B Target State and Status & Following Changes (§2.2.3.3.1.4.2.c)

Before 23 seconds following the change for each separate case in Step 7a above, verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

Step 7c: ADS-B Message Broadcasts – No ADS-B Target State and Status & Following Changes (§2.2.3.3.1.4.2.c)

After 25 seconds following the change for each separate case in Step 7a above, verify that the ADS-B Transmitting Subsystem continues broadcasting Aircraft Operational Status Messages at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

Step 8: Mutual Suppression Exception (§2.2.3.3.2.9)

If the Mutual Suppression Interface is provided, force the Mutual Suppression condition at a time, and for a duration, which insures that the next expected Aircraft Operational Status Message will be delayed, and verify that the Aircraft Operational Status Message is delayed.

Remove the Mutual Suppression condition, and verify that Aircraft Operational Status Messages resume at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

Step 9: ADS-B Message Broadcast Sixty-Second Timeout – Aircraft Operational Status Messages (§2.2.3.3.2.11.c & §2.2.3.3.2.12)

Interrupt the changing of the input data necessary for transmission of Aircraft Operational Status Messages (TYPE=31, Subtype=1) with new (valid) data, and after 60 seconds verify that the unchanged data fields are NOT cleared to ZERO.

Stop the input of data, and verify that the Aircraft Operational Status Messages (TYPE=31, Subtype=1) are no longer broadcast 60 ±1 seconds after the data becomes unavailable.

Step 10: ADS-B Message Broadcast Sixty Second Timeout – Aircraft Operational Status Messages (§2.2.3.3.2.11.c & §2.2.3.3.2.12)

Replace the Aircraft Operational Status Messages (TYPE=31, Subtype=1) with Aircraft Operational Status Messages (TYPE=31, Subtype=0), interrupt the changing of the input data necessary for transmission of Aircraft Operational Status Messages (TYPE=31, Subtype=0) with new (valid) data, and after 60 seconds verify that the unchanged data fields are NOT cleared to ZERO.

Stop the input of data, and verify that the Aircraft Operational Status Messages (TYPE=31, Subtype=0) are no longer broadcast 60 ±1 seconds after the data becomes unavailable.

2.4.3.3.2.6.3 Verification of "Extended Squitter Aircraft Status" ADS-B Event-Driven Message Broadcast Rate (§2.2.3.3.2.6.3)

Purpose/Introduction:

The rate at which the "Extended Squitter Aircraft Status" (TYPE=28) ADS-B Event-Driven Message (see §2.2.3.2.7.8), is being broadcast varies as defined in §2.2.3.3.1.4.3. Exceptions to these transmission rate requirements are specified in §2.2.3.3.2.9.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: ADS-B Message Broadcasts – No ADS-B Target State and Status & Extended Squitter Aircraft Status Emergency/Priority Status Messages (§2.2.3.3.1.4.3.a)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Extended Squitter Aircraft Status Messages with Emergency/Priority Status (TYPE=28, Subtype=1), but not ADS-B Target State and Status Messages (TYPE=29, Subtype=0), and verify that the ADS-B Transmitting Subsystem is broadcasting Extended Squitter Aircraft Status Emergency/Priority Status Messages at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 2: ADS-B Message Broadcasts – ADS-B Target State and Status & Extended Squitter Aircraft Status Emergency/Priority Status Messages (§2.2.3.3.1.4.3.b)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Extended Squitter Aircraft Status Messages with Emergency/Priority Status (TYPE=28, Subtype=1), and ADS-B Target State and Status Messages (TYPE=29, Subtype=0), and verify that the ADS-B Transmitting Subsystem is broadcasting both ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds, and Extended Squitter Aircraft Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 3: ADS-B Message Broadcasts – Emergency Status Termination (§2.2.3.3.1.4.3.b)

Terminate the Emergency State condition, and verify that the ADS-B Transmitting Subsystem ceases broadcasting of the Extended Squitter Aircraft Status Emergency/Priority Status Messages.

Step 4: Extended Squitter Aircraft Status Emergency/Priority Status Messages - Mutual Suppression Exception (§2.2.3.3.2.9)

Repeat Step 1 so that the ADS-B Transmitting Subsystem is broadcasting Extended Squitter Aircraft Status Emergency/Priority Status Messages at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

If the Mutual Suppression Interface is provided, force the Mutual Suppression condition at a time, and for a duration, which insures that the next expected ADS-B Extended Squitter Aircraft Status Message will be delayed, and verify that the ADS-B Extended Squitter Aircraft Status Message is delayed.

Remove the Mutual Suppression condition, and verify that ADS-B Extended Squitter Aircraft Status Messages resume at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 5: Extended Squitter Aircraft Status Emergency/Priority Status Messages - Mutual Suppression Exception (§2.2.3.3.2.9)

Repeat Step 2 so that the ADS-B Transmitting Subsystem is broadcasting Extended Squitter Aircraft Status Emergency/Priority Status Messages at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

If the Mutual Suppression Interface is provided, force the Mutual Suppression condition at a time, and for a duration, which insures that the next expected ADS-B Extended Squitter Aircraft Status Message will be delayed, and verify that the ADS-B Extended Squitter Aircraft Status Message is delayed.

Remove the Mutual Suppression condition, and verify that ADS-B Extended Squitter Aircraft Status Messages resume at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 6: ADS-B Message Broadcast Sixty Second Timeout – ADS-B Event-Driven Messages (§2.2.3.3.2.11.c & §2.2.3.3.2.12)

Interrupt the changing of the input data necessary for transmission of “Extended Squitter Aircraft Status” (TYPE=28), “Emergency/Priority Status” ADS-B Event-Driven Messages (Subtype=1) with new (valid) data, and after 60 seconds verify that the unchanged data fields are NOT cleared to ZERO.

Stop the input of data, and verify that the “Extended Squitter Aircraft Status” (TYPE=28), “Emergency/Priority Status” ADS-B Event-Driven Messages (Subtype=1) are no longer broadcast 60 ±1 seconds after the data becomes unavailable.

Step 7: No ADS-B Target State and Status while Broadcasting the 1090ES TCAS RA Broadcast Message (§2.2.3.3.1.4.3.a)

Provide the ADS-B Transmitting Subsystem with valid TCAS RA data necessary for the generation of ADS-B Extended Squitter Aircraft Status TCAS RA Broadcast Messages, but not ADS-B Target State and Status Messages

(TYPE=29, Subtype=0), and verify that the ADS-B Transmitting Subsystem is broadcasting Extended Squitter Aircraft Status TCAS RA Broadcast Messages (TYPE=28, Subtype=2) at a spacing uniformly distributed over the range of 0.75 to 0.85 seconds.

Step 8: Broadcasting Both ADS-B Target State and Status & Extended Squitter Aircraft Status TCAS RA Broadcast Messages (§2.2.3.3.1.4.3.b)

Provide the ADS-B Transmitting Subsystem with valid TCAS RA data necessary for the generation of ADS-B Extended Squitter Aircraft Status TCAS RA Broadcast Messages, and ADS-B Target State and Status Messages (TYPE=29, Subtype=0), and verify that the ADS-B Transmitting Subsystem is broadcasting both ADS-B Target State and Status Messages at a spacing uniformly distributed over the range of 1.2 to 1.3 seconds, and Extended Squitter Aircraft Status TCAS RA Broadcast Messages (TYPE=28, Subtype=2) at a spacing uniformly distributed over the range of 2.4 to 2.6 seconds.

Step 9: ADS-B Message Broadcasts – Termination of TCAS RA Broadcast (§2.2.3.3.1.4.3.b)

Terminate the TCAS RA condition, and verify that the ADS-B Transmitting Subsystem ceases broadcasting of the Extended Squitter Aircraft Status TCAS RA Broadcast Messages not less than 10 seconds after the RA Termination flag transitions from ZERO (0) to ONE (1) (§2.2.3.2.7.8.2).

2.4.3.3.2.7 Verification of "TYPE Code=23 (TEST)" ADS-B Event-Driven Message Broadcast Rate (§2.2.3.3.2.7)

Purpose/Introduction:

The "TEST" Message with Subtype=0 ADS-B Event-Driven Messages are broadcast ***NOT MORE Than*** ONCE each time the Event-Driven Test Information is updated to the ADS-B Transmitting Subsystem. The delay conditions specified in §2.2.3.3.2.9 are to be observed.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Update the TEST ADS-B Event-Driven Message and verify that it is broadcast only once. Repeat 10 times.

2.4.3.3.2.8 Verification of "TYPE Code 24 - 27" ADS-B Event-Driven Message Broadcast Rate (§2.2.3.3.2.8)

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

These messages are reserved for future expansion. When implemented perform the following test:

Update each of the implemented TYPE Code 24 to 27 ADS-B Event-Driven Messages in turn and verify that it is broadcast only once. Repeat 10 times.

2.4.3.3.2.9 Verification of ADS-B Message Transmission Scheduling (§2.2.3.3.2.9)

Purpose/Introduction:

An ADS-B Message scheduling function is used to determine the sequence of ADS-B Messages to be broadcast and to control the overall transmission rate of Event-Driven messages. As an exception to the general requirement for the transmission of ADS-B Messages, the scheduled message transmission is delayed if a Mutual Suppression interface is active.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope.

Measurement Procedure:

Step 1: Scheduling Function Verification (§2.2.3.3.2.9.a)

Appropriate test procedures to validate the requirements of §2.2.3.3.2.9.a are included in §2.4.3.3.2.9.1 and §2.4.3.3.2.9.2.

Step 2: Mutual Suppression Induced Message Delay (§2.2.3.3.2.9.b)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of ADS-B Aircraft Status Messages (TYPE=28, Subtype=1), and verify that the ADS-B Transmitting Subsystem is broadcasting ADS-B Aircraft Status Messages, with no Emergencies, no TCAS RAs and no Mode A Code changes, at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

If a Mutual Suppression Interface is provided, force a Mutual Suppression condition such that the next expected ADS-B Aircraft Status Message will be delayed, and verify that the delay occurs.

Remove the Mutual Suppression condition, and verify that ADS-B Aircraft Status Messages resume at a spacing uniformly distributed over the range of 4.8 to 5.2 seconds.

2.4.3.3.2.9.1 Verification of Position, Velocity and Identification Message Scheduling (§2.2.3.3.2.9.1)

Purpose/Introduction:

The priority for transmission (from highest to lowest) for the message types that are not Event-Driven is specified in §2.2.3.3.2.9.1. Provide a method for the generation of ADS-B Position, Velocity, and Identification Messages in a defined order, and for the verification that those messages have been reprioritized in their transmission order, according to the test steps that follow.

Measurement Procedure:

Step 1: Message Scheduling – Setup (§2.2.3.3.2.9.1)

Provide the ADS-B Transmitting Subsystem with valid data necessary for the generation of an ADS-B Surface Position Message.

Step 2: Message Scheduling – Airborne or Surface Position, Airborne Velocity, and Identification Messages (§2.2.3.3.2.9.1.a, b, c)

Beginning up to 15 milliseconds following the generation of the message pair in Step 1 above, and spaced by up to 15 milliseconds, generate the following series of messages in order as listed below:

1. A message of the TYPE and Subtype described in §2.2.3.3.2.9.1.c.

2. A message of the TYPE and Subtype described in §2.2.3.3.2.9.1.b.

3. A message (or message pair) of the TYPE and Subtype described in §2.2.3.3.2.9.1.a.

Step 3: Message Scheduling – Verification (§2.2.3.3.2.9.1.a, b, c)

Verify that the series of 3 message (or message pair) types, generated in Step 1 and Step 2 above, occur at a rate no more than that allowed for the message type (see §2.2.3.3.1.3, and §2.2.3.3.2.3 b & 3c), and occur in the following order:

1. A message (or message pair) of the TYPE and Subtype described in §2.2.3.3.2.9.1.a.

2. A message of the TYPE and Subtype described in §2.2.3.3.2.9.1.b.

3. A message of the TYPE and Subtype described in §2.2.3.3.2.9.1.c.

Step 4: Message Scheduling – Verification (§2.2.3.3.2.9.1.a, b, c)

Repeat Step 1, Step 2, and Step 3 for each type of Position Message (§2.2.3.3.2.9.1.a), and for each Subtype variation of Airborne Velocity Message (§2.2.3.3.2.9.1.b).

2.4.3.3.2.9.2 Verification of Event-Driven Message Scheduling (§2.2.3.3.2.9.2)

Appropriate test procedures required to validate the requirements of §2.2.3.3.2.9.2 are included in §2.4.3.3.1.4.6.1.

2.4.3.3.2.10 Verification of Maximum ADS-B Message Transmission Rates (§2.2.3.3.2.10)

Purpose/Introduction:

The maximum ADS-B Message transmission rate of non-transponder ADS-B Transmitter implementations may not exceed 6.2 transmitted messages per second, averaged over any 60 second interval.

Equipment Required:

Provide equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test through the operational interface. Provide a method of monitoring ADS-B broadcast messages output by the equipment under test. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Step 1: Airborne Message Scenario (§2.2.3.3.2.10)

Provide the ADS-B Transmitting Subsystem with the valid data necessary for the generation of (a) ADS-B Airborne Position Messages, (b) ADS-B Airborne Velocity Messages, (c) ADS-B Aircraft Identification and Category Messages, and (d) ADS-B Target State and Status Messages (TYPE=29, Subtype=0) resulting from more than two events per second, and over a period of several minutes verify that the ADS-B Transmitting Subsystem is broadcasting no more than a total of 6.2 messages per second, averaged over any 60 second interval.

Step 2: Surface Message Scenario (§2.2.3.3.2.10)

Provide the ADS-B Transmitting Subsystem with the valid data necessary for the generation of (a) ADS-B Surface Position Messages while changing aircraft position data by more than 10 meters every 30 seconds, (b) ADS-B Airborne Velocity Messages, (c) ADS-B Aircraft Identification and Category Messages, and (d) ADS-B Target State and Status Messages (TYPE=29, Subtype=0) resulting from more than two events per second, and over a period of several minutes verify that the ADS-B Transmitting Subsystem is broadcasting no more than a total of 6.2 messages per second, averaged over any 60 second interval.

2.4.3.3.2.11 Verification of ADS-B Message Timeout (§2.2.3.3.2.11)

ADS-B Message Timeout performance is tested in §2.4.3.3.2.2 through §2.4.3.3.2.8.

2.4.3.3.2.12 Verification of ADS-B Message Termination (§2.2.3.3.2.12)

Except for the requirement of Message Transmission suspension on Class B2 Ground Vehicles as specified in §2.2.3.3.2.12.g, other requirements for ADS-B Message Timeout performance are tested in §2.4.3.3.2.2 through §2.4.3.3.2.8.

Measurement Procedure:

Configure the Class B2 Non-Tansponder-Based Transmiting Subsystem for Ground Vehilces to transmit its required subset of ADS-B Messages. Input valid data and verify that the system is transmitting appropriate ADS-B Messages as required. Input additional data that indicates that the vehicle has crossed a boundary defined by the mapping function placing it outside of the user defined area. Verify that the broadcasts of all ADS-B Messages are suspended. Repeat this procedure for each boundary of the defined area entered into the mapping function database.

2.4.3.4 Verification of ADS-B Transmitted Message Error Protection (§2.2.3.4)

ADS-B Transmitted Error Protection performance was previously tested in §2.4.3.2.1.7.

2.4.4 Verification of ADS-B Receiver Characteristics (§2.2.4)

No specific test procedure is required to validate §2.2.4.

2.4.4.1 Verification of Minimum Triggering Level (MTL) Definition (§2.2.4.1)

No specific test procedure is required to validate §2.2.4.1 since appropriate procedures are provided in subsequent subparagraphs of this document.

2.4.4.2 Verification of Receivers Shared with a TCAS Unit (§2.2.4.2)

ADS-B receivers implemented as part of a TCAS unit **shall** demonstrate compliance with Test Procedures specified in the TCAS MOPS, RTCA DO-185B, §2.4.2.1.2 (EUROCAE ED-143, §2.4.2.1.2).

In addition to tests specified in the TCAS MOPS, RTCA DO-185B, §2.4.2.1.2 (EUROCAE ED-143, §2.4.2.1.2), TCAS units operating with receivers that are more sensitive than the MTL requirements specified in RTCA DO-185B, (EUROCAE ED-143) **shall** be submitted to the following test procedures provided through §2.4.4.4.

2.4.4.2.1 Verification of Dual Minimum Triggering Levels (§2.2.4.2.1)

No specific test procedure is required to validate §2.2.4.2.1.

2.4.4.2.1.1 Verification of TCAS Compatibility (§2.2.4.2.1.1)

Purpose/Introduction:

This test verifies that no more than 10% of ADS-B Messages received at a level of –78 dBm or below are passed to the TCAS surveillance function.

Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-78 dBm

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B **Input** Message

Apply **Input** at the receiver input port.

Step 2: Verify ADS-B **Input** Message Reception

Verify that no more than 10% of all ADS-B Messages are passed on to the TCAS surveillance function.

Step 3: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 and 2 on all other applicable receiver RF input ports of the UUT.

2.4.4.2.1.2 Verification of ADS-B Compatibility (§2.2.4.2.1.2)

Appropriate test procedures to verify the requirements of §2.2.4.2.1.2 are provided in §2.4.4.3.1.1.

2.4.4.2.2 Verification of Re-Triggerable Reply Processor (§2.2.4.2.2)

Purpose/Introduction:

The following procedures verify the capability of the TCAS shared ADS-B receiver to detect overlapping Mode-S replies or ADS-B Messages in the TCAS level range.

Inputs:

All Intruder Aircraft:

Frequency = 1090 MHz
Altitude Rate = 0 FPM

Intruder Aircraft 1:

Equipage = Mode-S ADS-B
Squitter Power = -50 dBm
Altitude = 8000 ft.
Range = 2 NM at T = 0 sec

Intruder Aircraft 2:

Equipage = Mode-S
Squitter Power = -44 dBm
Altitude = 8000 ft
Range = Maintained such that the leading edge of the first preamble pulse from Intruder 2 occurs 12 ± 1.0 μs later than the leading edge of the first preamble pulse from Intruder 1 throughout the scenario.

TCAS Aircraft:

Altitude = 8000 ft.
Altitude Rate = 0 FPM
Range = 0 NM
Sensitivity Level Selection = Automatic

ADS-B Message Format (Intruder 1):

All ADS-B Message transmissions **shall** have the following standard data field values:

"DF" = 17
"CA" = 0
"AA" = Any valid discrete address.

Mode-S Squitter Format (Intruder 2):

All Mode-S squitter transmissions **shall** have the following standard data field values:
"DF" = 11
"CA" = 0

"AA" = Any valid discrete address.

Conditions:

TCAS initialized and operating at T = 0 seconds. Intruders 1 and 2 **shall** each transmit squitters during the squitter listening period following each whisper-shout sequence and **shall** reply with a short special surveillance format (DF=0) to each TCAS discrete interrogation.

Scenario Description:

Both Intruders are co-altitude with TCAS and each transmits squitters when TCAS is in squitter listening mode and replies to discrete interrogations from TCAS. Intruder 2 is overlapping the Intruder 1 reply window.

Measurement Procedure:

The receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B and Mode-S Input Messages

Apply the message inputs defined above to the receiver input port.

Verify that the TCAS receiver detects intruder #2.

Step 2: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 on all other applicable receiver RF input ports of the UUT.

Step 3: Vary Signal Power Levels

Repeat Steps 1 and 2 with the following additional squitter power levels:

a. Intruder Aircraft 1 – Squitter Power = -30 dBm

Intruder Aircraft 2 – Squitter Power = -24 dBm

b. Intruder Aircraft 1 – Squitter Power = MTL + 3 dB

Intruder Aircraft 2 – Squitter Power = MTL + 9 dB

Verify that the TCAS receiver detects Intruder Aircraft #2 for each case.

2.4.4.3 Verification of Receivers Not Shared With TCAS (§2.2.4.3)

No specific test procedure is required to validate §2.2.4.3.

2.4.4.3.1 Verification of In-Band Acceptance and Re-Triggerable Capability (§2.2.4.3.1)

No specific test procedure is required to validate §2.2.4.3.1.

2.4.4.3.1.1 Verification of In-Band Acceptance and Dynamic Range (§2.2.4.3.1.1)

Appropriate test procedures to verify the requirements of §2.2.4.3.1.1 are provided in §2.4.4.3.1.1.1 and §2.4.4.3.1.1.2.

2.4.4.3.1.1.1 Verification of In-Band Acceptance (§2.2.4.3.1.1.a)

Purpose/Introduction:

This test verifies the compliance of the ADS-B receiver with the sensitivity requirements specified for the particular ADS-B equipage class.

Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

“DF”	=	17
“CA”	=	0
“AA”	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-68 dBm

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages

Apply **Input** at the receiver input port.

Step 2: Establish UUT Receiver MTL

Decrease the input power level and determine the minimum RF signal level required to produce a 90 percent ADS-B Message reception rate by the UUT receiver.

This value plus the loss line value represents the measured MTL of the UUT ADS-B receiver.

Verify that the measured MTL is in compliance with the limits specified in §2.2.4.3.1.1.a for the UUT equipment class.

Step 3: Verify UUT Receiver MTL over the Operational Frequency Range

Vary the RF signal frequency over the range of 1089 to 1091 MHz and determine the variation in RF signal level required to produce 90 percent ADS-B Message reception rate by the UUT receiver.

Verify that the measured MTL continues to comply with the limits specified in §2.2.4.3.1.1.a for the UUT equipment class.

Step 4: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.4.4.3.1.1.2 Verification of Dynamic Range (§2.2.4.3.1.1.b, §2.2.4.3.1.1.c)

Purpose/Introduction:

This test verifies that the ADS-B receiver can detect and decode valid ADS-B Messages over the equipment's specified dynamic range.

Input:

Equipment:

Provide a method of providing the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-68 dBm

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages

Apply **Input** at the receiver input port.

Step 2: Establish UUT Receiver MTL

Decrease the input power level and determine the minimum RF signal level required to produce 90 percent ADS-B Message reception rate by the UUT receiver.

This value plus the loss line value represents the measured MTL of the UUT ADS-B receiver.

Step 3: Verify UUT Receiver Dynamic Range

Increase the input signal power level to MTL + 3 dB.

Verify that the receiver properly detects and decodes at least 99% of all ADS-B Messages received.

Increase the input signal power level in 10 dB steps up to a signal level of -21 dBm.

At each step, verify that the receiver properly detects and decodes at least 99% of all ADS-B Messages received.

Step 4: Verify Class A3 UUT Receiver Performance

Decrease the input signal power level to –87 dBm. Verify that the receiver properly detects and decodes at least 15% of all ADS-B Messages input.

Step 5: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 4 on all other applicable receiver RF input ports of the UUT.

2.4.4.3.1.2 Verification of Re-Triggerable Capability (§2.2.4.3.1.2)

Purpose/Introduction:

The following test procedures verify the capability of the Standalone ADS-B receiver to detect overlapping ADS-B broadcast messages.

Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-50 dBm

Followed by a second Valid Mode S Extended Squitter:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address different from the first one
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	–42 dBm

Starting 6.0 ±1.0 μsec later than the leading edge of the first ADS-B Message.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Re-Trigger Capability - Part 1

Apply **Input** at the receiver input and verify that at least the reply ratio in the following table of the second valid ADS-B Messages are correctly decoded.

Receiver Class	**Class A1S/A1**	**Class A2**	**Class A3**
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93

Step 2: Re-Trigger Capability - Part 2

Repeat Step 1 with the **Input** signal power level at MTL + 6 dB for the first ADS-B Message and MTL + 14 dB for the second ADS-B Message.

Step 3: Re-Trigger Capability - Part 3

Repeat Step 1 with **Input** level at -32 dBm for the first ADS-B Message and -24 dBm for the second ADS-B Message.

Step 4: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.4.4.3.2 Verification of Out-of-Band Rejection (§2.2.4.3.2)

Purpose/Introduction:

This test verifies that the ADS-B out-of-band rejection is in accordance with the specified values.

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	MTL + 3 dB Where MTL is the measured value of MTL made at 1090 MHz

Input B:

Same as Input A with:

Frequency	=	1084.5 MHz
Power	=	MTL + 6 dB

Input C:

Same as Input A with:

Frequency	=	1080.0 MHz
Power	=	MTL + 23 dB

Input D:

Same as Input A with:

Frequency	=	1075.0 MHz
Power	=	MTL + 43 dB

Input E:

Same as Input A with:

Frequency	=	1065.0 MHz
Power	=	MTL + 63 dB

Input F:

Same as Input A with:
Frequency = 1095.5 MHz
Power = MTL + 6 dB

Input G:

Same as Input A with:
Frequency = 1100.0 MHz
Power = MTL + 23 dB

Input H:

Same as Input A with:
Frequency = 1105.0 MHz
Power = MTL + 43 dB

Input I:

Same as Input A with:
Frequency = 1115.0 Mhz
Power = MTL + 63 dB

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Apply Initial ADS-B Input Messages

Apply Input B at the receiver input port and decrease the power level until the percentage of decoded ADS-B Messages is less than or equal to 90 percent.

Verify that the measured signal power level required to produce a message decoding percentage of greater than or equal to 90 percent is greater than the limit specified in Table 2-80 of §2.2.4.3.2.

Step 2: Vary the Input Signal Power and Frequency

Repeat Step 1 using inputs C, D, E, F, G, H and I.

Step 3: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 and 2 on all other applicable receiver RF input ports of the UUT.

2.4.4.3.3 Verification of Dynamic Minimum Trigger Level (DMTL) (§2.2.4.3.3)

Purpose/Introduction:

This test verifies that, when DMTL control is implemented (see §2.2.4.3.3), then the ADS-B receiver DMTL is capable of rejecting low level signals during a valid squitter reception and that DMTL is capable of recovering in not more than 128 microseconds after the leading edge of the first preamble pulse of a valid ADS-B Message.

Note: *This test procedure is only applicable to equipment that do not use the enhanced reception techniques. That is, it is not applicable to equipage Classes A1S, A1, A2 and A3.*

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-61 dBm

Overlapped by a pulse having the following characteristics:

Pulse Width	=	120 ±1 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-69 dBm

Starting 0.7 ±0.2 μsec after the leading edge of the first preamble pulse of the ADS-B Message.

Input B:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-40 dBm

Overlapped by a pulse having the following characteristics:

Pulse Width	=	120 ±1 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-49 dBm

Starting 0.7 ±0.2 μsec after the leading edge of the first preamble pulse of the ADS-B Message.

<u>Input C:</u>

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

“DF”	=	17
“CA”	=	0
“AA”	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-21 dBm

Overlapped by a pulse having the following characteristics:

Pulse Width	=	120 ±1 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-30 dBm

Starting 0.7 ±0.2 μsec after the leading edge of the first preamble pulse of the ADS-B Message.

<u>Input D:</u>

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

“DF”	=	17
“CA”	=	0
“AA”	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-21 dBm

Followed by a second Valid ADS-B Message having:

“DF”	=	17
“CA”	=	0
“AA”	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-60 dBm

Starting 129 ±1 μsec after the leading edge of the first preamble pulse of the first ADS-B Message.

Input E:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-70 dBm

Preceded by a pulse having the following characteristics:

Pulse Width	=	0.50 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-60 dBm

Starting 4.0 μsec before the leading edge of the first preamble pulse of the ADS-B Message.

Input F:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-70 dBm

Preceded by a pulse having the following characteristics:

Pulse Width	=	0.50 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-60 dBm

Starting 9.0 μsec before the leading edge of the first preamble pulse of the ADS-B Message.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: DMTL Desensitization - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the valid ADS-B Messages are correctly decoded.

Step 2: DMTL Desensitization - Part 2

Repeat Step 1 using **Input B**.

Step 3: DMTL Desensitization - Part 3

Repeat Step 1 using **Input C**.

Step 4: DMTL Recovery - Part 4

Apply **Input D** at the receiver input and verify that at least 90 percent of the second valid ADS-B Messages are correctly decoded.

Step 5: DMTL Desensitization after a Single Pulse

Apply **Input E** at the receiver input and verify that no more than 10 percent of the valid ADS-B Messages are correctly decoded.

Step 6: DMTL Recovery after a Single Pulse

Apply **Input F** at the receiver input and verify that at least 90 percent of the valid ADS-B Messages are correctly decoded.

2.4.4.3.4 Verification of 1090 MHz ADS-B Message Reception Techniques (§2.2.4.3.4)

No specific test procedure is required to validate §2.2.4.3.4.

2.4.4.3.4.1 Verification of ADS-B Message Reception (§2.2.4.3.4.1)

Appropriate test procedures required to validate §2.2.4.3.4.1 are provided in §2.4.4.3.3.

2.4.4.3.4.2 Verification of Narrow Pulse Discrimination (§2.2.4.3.4.2)

Purpose/Introduction:

This test verifies that the ADS-B receiver DMTL is responsive neither to short pulses nor to TACAN/DME pulses.

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-61 dBm

Preceded by a pulse having the following characteristics:

Pulse Width	=	0.20 ±0.05 μsec
Pulse Rise Time	=	0.05 to 0.1 μsec
Pulse Fall Time	=	0.05 to 0.2 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-61 dBm

Starting 1.0 ±0.2 μsec earlier than the leading edge of the first preamble pulse of the ADS-B Message.

Input B:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-61 dBm

Preceded by a pulse having the following characteristics:

Pulse Width	=	3.00 ±0.20 μsec
Pulse Rise Time	=	0.60 ±0.1 μsec
Pulse Fall Time	=	0.60 ±0.1 μsec
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-61 dBm

Starting 4.0 ±0.2 μsec earlier than the leading edge of the first preamble pulse of the ADS-B Message.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Narrow Pulse Discrimination - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the valid ADS-B Messages are correctly decoded.

Step 2: Narrow Pulse Discrimination- Part 2

Repeat the Step 1 procedure while increasing the narrow pulse amplitude in 5 dB steps up to a signal level of -21 dBm.

At each step, verify that the receiver properly detects and decodes at least 99% of all ADS-B Messages received.

Step 3: TACAN/DME Discrimination - Part 1

Repeat Step 1 using **Input B**.

Step 4: TACAN/DME Discrimination - Part 2

Repeat the Step 3 procedure while increasing the TACAN/DME pulse amplitude in 5 dB steps up to a signal level of -21 dBm.

At each step, verify that the receiver properly detects and decodes at least 99% of all ADS-B Messages received.

2.4.4.3.4.3 Verification of TACAN and DME Discrimination (§2.2.4.3.4.3)

Appropriate test procedures required to validate §2.4.4.3.4.3 are provided in §2.4.4.3.4.2.

2.4.4.3.4.4 Verification of Pulse Characteristics of Received ADS-B Messages (§2.2.4.3.4.4)

No specific test procedure is required to validate §2.2.4.3.4.4.

2.4.4.3.4.5 Message Formats (§2.2.4.3.4.5)

Appropriate test procedures to validate §2.2.4.3.4.5 have previously been provided in §2.4.4.3.1.1 through §2.4.4.3.4.4.

2.4.4.3.4.6 Description of 1090 MHz ADS-B Message Received Signals (§2.2.4.3.4.6)

No specific test procedure is required to validate §2.2.4.3.4.6.

2.4.4.3.4.7 Verification of ADS-B Signal Reception (§2.2.4.3.4.7)

No specific test procedure is required to validate §2.2.4.3.4.7.

2.4.4.3.4.7.1 Verification of Criteria for ADS-B Message Transmission Pulse Detection (§2.2.4.3.4.7.1 and §2.2.4.3.4.7.2)

Purpose/Introduction:

These test procedures verify that the ADS-B reply processor correctly detects the presence of a valid ADS-B preamble whose pulse characteristics are within the allowable limits and rejects preambles having pulse spacing and position characteristics that are outside the allowable limits.

Note: *This test is not applicable to equipment which uses the enhanced reception techniques. That is, it is not applicable to equipage Classes A1S, A1, A2 and A3. The enhanced preamble detection requirements for this equipment are tested in §2.4.4.4.2.2.*

Reference Input:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-23 dBm (for the first preamble pulse level)

Input A:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-146: Input A: Preamble Pulse Characteristics

Input A: Preamble Pulse Characteristics					
Pulse	**Rise time** (µsec)	**Fall time** (µsec)	**Δ Width** (µsec)	**Δ Position** (µsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.05	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.05	-0.125	+2
3	0.05 - 0.1	0.05 - 0.2	+0.05	+0.125	+2
4	0.05 - 0.1	0.05 - 0.2	-0.05	-0.125	0

Input B:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-147: Input B: Preamble Pulse Characteristics

Input B: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	-0.3	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
3	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
4	0.05 - 0.1	0.05 - 0.2	-0.3	0	0

Input C:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-148: Input C: Preamble Pulse Characteristics

Input C: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	0	—	—
2	0.05 - 0.1	0.05 - 0.2	0	+0.2	0
3	0.05 - 0.1	0.05 - 0.2	0	+0.2	0
4	0.05 - 0.1	0.05 - 0.2	0	+0.2	0

Input D:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-149: Input D: Preamble Pulse Characteristics

Input D: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+4.5	—	—
2	Pulse Not Present				
3	Pulse Not Present				
4	Pulse Not Present				

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 2: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 2

Repeat Step 1 with the signal power level at -65 dBm.

Step 3: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 1

Apply **Input B** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 4: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 2

Repeat Step 3 with the signal power level at -65 dBm.

Step 5: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 1

Apply **Input C** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 6: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 2

Repeat Step 5 with the signal power level at -65 dBm.

Step 7: Preamble Single Pulse - Part 1

Apply **Input D** at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 8: Preamble Single Pulse - Part 2

Repeat Step 7 with the signal power level at -65 dBm.

2.4.4.3.4.7.2 Verification of Criteria for Preamble Acceptance (§2.2.4.3.4.7.2)

Appropriate test procedures required to validate §2.2.4.3.4.7.2 are provided in §2.4.4.3.4.7.1.

2.4.4.3.4.7.3 Verification of Criteria for Data Block Acceptance in ADS-B Message Signals (§2.2.4.3.4.7.3)

Purpose/Introduction:

This test verifies that ADS-B Messages are accepted when DF=17 or DF=18 and when no more than seven consecutive bits fail the confidence test, as specified by §2.2.4.3.4.7.3.

Input A:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-50 dBm

The normal data block content **shall** be modified to contain energy throughout both halves (i.e., chips) of bit positions 33 to 39. The amplitude of the pulse in the half that would ordinarily contain no energy **shall** be 2 dB below the amplitude of the normal pulse in the other half of the bit position. The data values in bit positions 33 to 39 **shall** be chosen so that at least one of these bits will be detected by the UUT with the incorrect bit value.

Input B:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	18
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-50 dBm

The normal data block content **shall** be modified to contain energy throughout both halves (i.e., chips) of bit positions 33 to 39. The amplitude of the pulse in the half that would ordinarily contain no energy **shall** be 2 dB below the amplitude of the normal pulse in the other half of the bit position. The data values in bit positions 33 to 39 **shall** be chosen so that at least one of these bits will be detected by the UUT with the incorrect bit value.

Input C:

Equipment:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-50 dBm

The normal data block content **shall** be modified to contain energy throughout both halves (i.e., chips) of bit positions 33 to 40. The amplitude of the pulse in the half that would ordinarily contain no energy **shall** be 2 dB below the amplitude of the normal pulse in the other half of the bit position. The data values in bit positions 33 to 40 **shall** be chosen so that at least one of these bits will be detected by the UUT with the incorrect bit value.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level **shall** be adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures **shall** be lowered by 3 dB.

Step 1: Valid DF=17 ADS-B Message

Apply **Input A** at the receiver input and verify that all ADS-B Messages are correctly decoded.

Step 2: Valid DF=18 ADS-B Message

Apply **Input B** at the receiver input and verify that all ADS-B Messages are correctly decoded.

Step 3: Corrupted DF=17 ADS-B Messages - Part 1

Apply **Input C** at the receiver input and verify that ADS-B Messages are not decoded.

Step 4: Repeat on all Applicable Receiver Input Ports

Repeat Steps 1 through 3 on all other applicable receiver RF input ports of the UUT.

2.4.4.3.5 Verification of ADS-B Receiver Duty Factor (§2.2.4.3.5)

Purpose/Introduction:

Available ADS-B receiver duty factor (i.e., the percentage of time that the ADS-B Message Reception function is able to receive and process ADS-B Messages at the required ADS-B MTL), when the receiver is shared with another receiving function using the 960-1215 MHz band, is an important consideration in meeting the intended ranges of operation for ADS-B equipment. The available ADS-B receiver duty factor must be 90 percent or greater, as specified in §2.2.4.3.5, averaged over a 10 second period. As an exception, if the available ADS-B receiver duty factor is less than 90 percent, techniques for achieving equivalent performance may be proposed and substantiated by the following analysis procedure.

Analysis Procedure:

Note that due to the many types of configurations and techniques that may be implemented in the ADS-B Receiving Subsystem, verification of the Receiver Duty Factor is to be done by analysis. As such, this procedure does not provide a direct test procedure.

This analysis **shall** take into consideration all effects presented to the ADS-B Receiving Subsystem for an interference environment equivalent to the LA2020 traffic scenario used in Appendix P.

Step 1: Identify Functions that Degrade Receiver Availability

The first step of the analysis is for the ADS-B Receiver manufacturer to specifically identify all functions that may preclude the use of the ADS-B Receiver to properly receive ADS-B Messages. Examples of such functions are provided (but not limited to) as follows:

a. Receiver Self-Test

b. Antenna Self-Test

c. Receiver being used for other than ADS-B Receiving Subsystems

d. Antenna being used for other than ADS-B Receiving Subsystems

e. Receiver being suppressed by other in-band systems, i.e., Mode-S Transponder, TCAS, DME, JTIDS, etc.

f. Antenna operating in other than omni-directional mode.

For each function that may preclude the use of the ADS-B Receiver to properly receive ADS-B Messages, the analysis **shall** establish the probability of the Receiver not being available to process ADS-B Messages.

Step 2: Establish the Improvements Environment for the Analysis

The Receiver manufacturer **shall** specifically identify all functions that may improve the capability of the ADS-B Receiver to receive ADS-B Messages at the MTL levels specified in §2.2.4.3.1.1, Table 2-79. Examples of such functions are provided (but not limited to) as follows:

a. Improved antenna gain

b. Improved Receiver gain (i.e., lower MTL capability)

c. Improved message or signal processing techniques

d. Improved Error Correction techniques

For each function that improves the capability of the ADS-B Receiver to receive ADS-B Messages, the analysis **shall** establish the message decode probability that improvement will realize in the effective Receiver availability at the MTL levels specified in §2.2.4.3.1.1, Table 2-79.

Step 3: Establish the Equivalent Receiver Performance

From the analysis performed in step 1 and 2 demonstrate that equivalent receiver performance is sufficient to meet the required equipage class range performance. Demonstrate that [Receiver Availability (step 1) plus (+) Reception Improvements (step 2)] is not less than 90% of the total time when averaged over a processing time of 10 seconds.

2.4.4.4 Verification of Enhanced Squitter Reception Techniques (§2.2.4.4)

No specific test procedures are required to validate §2.2.4.4.

2.4.4.4.1 Verification of the Need for Enhanced Squitter Reception Techniques (§2.2.4.4.1)

No specific test procedures are required to validate §2.2.4.4.1.

2.4.4.4.2 Verification for the Enhanced Squitter Reception Technique Overview (§2.2.4.4.2)

Purpose/Introduction:

Enhanced squitter reception techniques have been developed (see Appendix I) that provide the ability to receive squitters with multiple overlapping Mode A/C FRUIT. Class A1S, A1, A2 and A3 equipment must demonstrate compliance with test procedures specified in §2.4.4.4.2.1 through §2.4.4.4.3.

Note: *The full set of enhanced techniques are applicable to Class A2 and A3 receiving equipment. Class A1S and A1 receiving equipment requires only a subset of the enhanced reception capabilities, and this is reflected in the test procedures of §2.4.4.4.2.4 and §2.4.4.4.2.5.*

2.4.4.4.2.1 Test Equipment Requirements

Note: *This section defines the tests that are conducted to evaluate the performance of the improved preamble and enhanced squitter reception techniques of the equipment under test.*

The tests consist of injecting special waveforms to test the limits of preamble detection. The tests then proceed to inject a known Mode S Extended Squitter waveform at a nominal power level with a defined FRUIT overlap scenario to test the reception of the Extended Squitter data block. These tests are followed by a test scenario where Mode S FRUIT precedes a nominal Mode S Extended Squitter waveform to measure the re-triggering capability. Finally, a test is conducted to verify that the sliding window error correction technique is not used.

The success criteria for the tests require the monitoring of the Mode S Extended Squitter data content. This data must be available for test monitoring. Report level monitoring is not adequate.

In the following tests, the parameter **T** defines the number of trials that are to be executed. Unless otherwise indicated, **T** equals 1000.

2.4.4.4.2.1.1 Mode A/C Fruit Signal Source Requirements

Five RF sources **shall** be provided that are capable of generating Mode A/C 14-pulse replies. Each FRUIT source **shall** be capable of the following:

The waveform **shall** consist of framing pulses and an average of five data pulses. The data content of the FRUIT reply **shall** be pseudo randomly varied each time a FRUIT reply is generated. The data pulses **shall** be uniformly pseudo randomly distributed across the 12 data bit positions (the **X** pulse position **shall** not be used).

Each FRUIT source **shall** be able to generate Mode A/C replies at received power levels ranging from –80 to –58 dBm as required within plus or minus 1 dB.

The FRUIT sources should be able to sustain a repetition rate of at least 100 replies per second.

The signals for each of the FRUIT sources **shall** be non-coherent with any of the other FRUIT sources and the Extended Squitter signal source (§2.4.4.4.2.1.3).

The leading edge of the P1 pulse of the Extended Squitter waveform **shall** be defined as t=0. The timing of the generation of the beginning of the F1 pulse of each FRUIT reply **shall** be controllable to be uniformly pseudo randomly distributed over the interval -20 to +100 microseconds (Combined Extended Squitter preamble and data block with Mode A/C FRUIT test).

The pseudo random timing of the generation of FRUIT replies from each FRUIT source **shall** be independent of the timing of the other FRUIT sources.

2.4.4.4.2.1.2 Mode S Fruit Signal Source Requirements

One RF source **shall** be provided that is capable of generating a Mode S 112-bit transmission as follows:

The content of the 112-bit Mode S transmission **shall** consist of a valid DF code (16, 17, 18, 20, 21, or 24), an 83-bit field that is set pseudo randomly for each transmission, and a 24-bit PI field appropriate for the content of this transmission. If an Extended Squitter message type is used (DF=17 or 18) the test equipment **shall** be capable of distinguishing the reception of the desired Extended Squitter from that of the Mode S FRUIT.

The Mode S FRUIT source should be able to sustain a squitter rate of at least 100 squitters per second.

The Mode S FRUIT source **shall** be capable of generating a signal power equal to 12 dB above the minimum MTL required for the equipment class being tested within plus or minus 1 dB with no more than 1 dB droop.

The signal for the Mode S FRUIT source **shall** be non-coherent with the Extended Squitter signal source (§2.4.4.4.2.1.3).

The leading edge of the P1 pulse of the Extended Squitter waveform **shall** be defined as t=0. The timing of the generation of the beginning of the P1 pulse of the Mode S FRUIT waveform **shall** be controllable to be uniformly pseudo randomly distributed over a defined interval or fixed as required by the test procedure. The following define the timing of the Mode S FRUIT source relative to the Extended Squitter waveform:

+8 to +90 microseconds (Data Block Tests with Mode S Fruit)

-112 to –6 microseconds (Re-triggering Tests with Varying Position Mode S Fruit)

-6 microseconds (Re-triggering Tests with Fixed Position Mode S Fruit)

2.4.4.4.2.1.3 Extended Squitter Signal Source Requirements

One RF source **shall** be provided that is capable of generating a 112-bit Extended Squitter transmissions with no more than 1 dB droop as follows:

The Extended Squitter power level **shall** be adjustable ranging from –21 dBm to –84 dBm within plus or minus 1 dB as required by the test procedures.

The Extended Squitter signal source should be able to sustain a squitter rate of at least 100 squitters per second.

Unless otherwise required, the contents of the Extended Squitter transmission **shall** consist of the five-bit DF field set to 17, an 83-bit field that is set pseudo randomly for each Extended Squitter transmission except for ME Field bits 1 to 5 (the Format TYPE Code) which may be set to a fixed value, and a 24-bit PI field appropriate for the content of this transmission.

Note: *The Four-Pulse Preamble Detection tests and the Preamble Validation Tests do not require pseudo-random message content, all other test procedures do.*

Provision **shall** be made to record the contents of each Extended Squitter transmission

Note: *This information is required to check for undetected errors.*

The Extended Squitter signal source **shall** have the capability to selectively control the width and/or position of individual preamble pulses with at least 25 nanosecond resolution. The Extended Squitter signal source **shall** also provide the capability of individually omitting preamble pulses or any of the first 5 data pulses from the transmission.

2.4.4.4.2.2 Four-Pulse Preamble Detection Tests

Purpose/Introduction:

These tests verify that the ADS-B reply processor correctly detects the presence of a valid ADS-B preamble whose pulse characteristics are within the allowable limits and rejects preambles having pulse spacing and position characteristics that are outside the allowable limits.

Reference Input:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-23 dBm (for the first preamble pulse level)

Input A:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-150: Input A: Preamble Pulse Characteristics

Input A: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.05	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.05	+0.100	+2
3	0.05 - 0.1	0.05 - 0.2	+0.05	+0.100	+2
4	0.05 - 0.1	0.05 - 0.2	-0.05	+0.100	0

Input B:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-151: Input B: Preamble Pulse Characteristics

Input B: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+0.05	—	—
2	0.05 - 0.1	0.05 - 0.2	-0.05	-0.100	+2
3	0.05 - 0.1	0.05 - 0.2	+0.05	-0.100	+2
4	0.05 - 0.1	0.05 - 0.2	-0.05	-0.100	0

Input C:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-152: Input C: Preamble Pulse Characteristics

Input C: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	-0.3	—	—
2	0.05 - 0.1	0.05 - 0.2	-3.5	0	0
3	Pulse Not Present				
4	Pulse Not Present				

Note: *Input C sets up a preamble where only P1 and P2 have actual leading edges, while P3 and P4 have pulse positions provided by the extended P2 pulse. All pulse positions and leading edges are at nominal positions. This test input verifies that the UUT accepts a preamble with the minimum 2 actual leading edges using P1 and P2. The test procedure requires that the UUT accepts this input at a rate of at least 90%.*

Input D:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-153: Input D: Preamble Pulse Characteristics

Input D: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+1.0	—	—
2	Pulse Not Present				
3	0.05 - 0.1	0.05 - 0.2	+1.0	0	0
4	Pulse Not Present				

Note: *Input D sets up a preamble where only P1 and P3 have actual leading edges, while P2 and P4 have pulse positions provided by the extended P1 and P3 pulses. All pulse positions and leading edges are at nominal positions. This test input verifies that the UUT accepts a preamble with the minimum 2 actual leading edges using P1 and P3. The test procedure requires that the UUT accepts this input at a rate of at least 90%.*

Input E:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-154: Input E: Preamble Pulse Characteristics

Input E: Preamble Pulse Characteristics					
Pulse	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+3.5	—	—
2	Pulse Not Present				
3	Pulse Not Present				
4	0.05 - 0.1	0.05 - 0.2	0	0	0

Note: *Input E sets up a preamble where only P1 and P4 have actual leading edges, while P2 and P3 have pulse positions provided by the extended P1 pulse. All pulse positions and leading edges are at nominal positions. This test input verifies that the UUT accepts a preamble with the minimum 2 actual leading edges using P1 and P4. The test procedure requires that the UUT accepts this input at a rate of at least 90%.*

Input F:

Same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-155: Input F: Preamble Pulse Characteristics

Input F: Preamble Pulse Characteristics					
Pulse	**Rise time** (µsec)	**Fall time** (µsec)	**Δ Width** (µsec)	**Δ Position** (µsec)	**Δ Amplitude** (dB)
1	0.05 - 0.1	0.05 - 0.2	+1.3	-0.3	—
2	Pulse Not Present				
3	0.05 - 0.1	0.05 - 0.2	0	0	0
4	0.05 - 0.1	0.05 - 0.2	0	0	0

Note: *Input F sets up a preamble where only P3 and P4 provide actual leading edges within the allowable position limits, while P1 and P2 have pulse positions provided by the extended P1 pulse. Pulse positions and leading edges are located at nominal positions. This test input verifies that the UUT accepts a preamble with the minimum 2 actual leading edges using P3 and P4. The test procedure requires that the UUT accepts this input at a rate of at least 90%.*

Input G through W:

The Inputs for G through W are the same as the **Reference Input**, but having the following preamble pulse characteristics:

Table 2-156: Inputs G through W: Preamble Pulse Characteristics

Input Set	**Pulse**	**Rise time** (µsec)	**Fall time** (µsec)	**Δ Width** (µsec)	**Δ Position** (µsec)	**Δ Amplitude** (dB)
Input G	1	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	—
	2	0.05 - 0.1	0.05 - 0.2	0	0	0
	3	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	0
	4	0.05- 0.1	0.05 - 0.2	0	0	0
Input H	1	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	—
	2	0.05 - 0.1	0.05 - 0.2	0	0	0
	3	0.05 - 0.1	0.05 - 0.2	+1.0	0	0
	4	Pulse Not Present				
Input I	1	0.05 - 0.1	0.05 - 0.2	-0.3	—	—
	2	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
	3	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
	4	0.05 - 0.1	0.05 - 0.2	-0.3	0	0
Input J	1	0.05 - 0.1	0.05 - 0.2	+4.5	—	—
	2	Pulse Not Present				
	3	Pulse Not Present				
	4	Pulse Not Present				
Input K	1	0.05 - 0.1	0.05 – 0.2	0	—	—
	2	0.05 - 0.1	0.05 – 0.2	+3.5	-0.2	0

Input Set	Pulse	Rise time (µsec)	Fall time (µsec)	Δ Width (µsec)	Δ Position (µsec)	Δ Amplitude (dB)
	3	Pulse Not Present				
	4	Pulse Not Present				
Input L	1	0.05 - 0.1	0.05 – 0.2	0	—	—
	2	0.05 - 0.1	0.05 – 0.2	+3.5	+0.2	0
	3	Pulse Not Present				
	4	Pulse Not Present				
Input M	1	0.05 - 0.1	0.05 - 0.2	+1.0	—	—
	2	Pulse Not Present				
	3	0.05 - 0.1	0.05 - 0.2	+1.0	-0.2	0
	4	Pulse Not Present				
Input N	1	0.05 - 0.1	0.05 - 0.2	+1.0	—	—
	2	Pulse Not Present				
	3	0.05 - 0.1	0.05 - 0.2	+1.0	+0.2	0
	4	Pulse Not Present				
Input O	1	0.05 - 0.1	0.05 - 0.2	+3.5	—	—
	2	Pulse Not Present				
	3	Pulse Not Present				
	4	0.05 - 0.1	0.05 - 0.2	0	-0.2	0
Input P	1	0.05 - 0.1	0.05 - 0.2	+3.5	—	—
	2	Pulse Not Present				
	3	Pulse Not Present				
	4	0.05 - 0.1	0.05 - 0.2	0	+0.2	0
Input Q	1	0.05 - 0.1	0.05 - 0.2	+1.3	-0.3	—
	2	Pulse Not Present				
	3	0.05 - 0.1	0.05 - 0.2	0	-0.125	0
	4	0.05 - 0.1	0.05 - 0.2	0	+0.125	0
Input R	1	0.05 - 0.1	0.05 - 0.2	+1.3	-0.3	—
	2	Pulse Not Present				
	3	0.05 - 0.1	0.05 - 0.2	0	+0.125	0
	4	0.05 - 0.1	0.05 - 0.2	0	-0.125	0
Input S	1	0.05 – 0.1	0.05 - 0.2	+0.3	-0.3	—
	2	0.05 – 0.1	0.05 - 0.2	0	-0.125	0
	3	0.05 – 0.1	0.05 - 0.2	+0.3	-0.3	0
	4	0.05 – 0.1	0.05 - 0.2	0	+0.125	0
Input T	1	0.05 – 0.1	0.05 - 0.2	+0.3	-0.3	—

Input Set	**Pulse**	**Rise time** (μsec)	**Fall time** (μsec)	**Δ Width** (μsec)	**Δ Position** (μsec)	**Δ Amplitude (dB)**
	2	0.05 - 0.1	0.05 - 0.2	0	+0.125	0
	3	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	0
	4	0.05 - 0.1	0.05 - 0.2	0	-0.125	0
Input U	1	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	—
	2	0.05 - 0.1	0.05 - 0.2	0	-0.125	0
	3	0.05 - 0.1	0.05 - 0.2	+1.0	+.125	0
	4	Pulse Not Present				
Input V	1	0.05 - 0.1	0.05 - 0.2	+0.3	-0.3	—
	2	0.05 - 0.1	0.05 - 0.2	0	+0.125	0
	3	0.05 - 0.1	0.05 - 0.2	+1.0	-.125	0
	4	Pulse Not Present				
Input W	1	Pulse Not Present				
	2	0.05 - 0.1	0.05 – 0.2	0	0	0
	3	0.05 - 0.1	0.05 – 0.2	0	0	0
	4	0.05 - 0.1	0.05 – 0.2	0	0	0

Notes:

1. *Input G sets up a preamble where only P2 and P4 provide actual leading edges within the allowable position limits, while P1 and P3 have pulse positions. Pulse positions and leading edges are located at nominal positions. This test input verifies that the UUT accepts a preamble with the minimum 2 actual leading edges using P2 and P4. The test procedure requires that the UUT accepts this input at a rate of at least 90%.*
2. *Input H sets up a preamble where only P2 and P3 provide actual leading edges within the allowable position limits, while P1 and P4 have pulse positions provided by the extended P1 and P3 pulses. Pulse positions and leading edges are located at nominal positions. This test input verifies that the UUT accepts a preamble with the minimum 2 actual leading edges using P2 and P3. The test procedure requires that the UUT accepts this input at a rate of at least 90%.*
3. *Input K sets up a preamble where only P1 and P2 have actual leading edges, while P3 and P4 will have pulse positions provided by the extended P2 pulse. The P2 leading edge position is offset by -0.2 microseconds. This test input step verifies that the UUT uses a maximum ± 0.1 sample pulse leading edge position tolerance using P1 and P2. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
4. *Input L sets up a preamble where only P1 and P2 have actual leading edges, while P3 and P4 will have pulse positions provided by the extended P2 pulse. The P2 leading edge position is offset by +0.2 microseconds. This test input step verifies that the UUT uses a maximum ± 0.1 sample pulse leading edge position tolerance using P1 and P2. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
5. *Input M sets up a preamble where only P1 and P3 have actual leading edges, while P2 and P4 will have pulse positions provided by the extended P1 and P3 pulses. The P3 leading edge position is offset by -0.2 microseconds. This test input step verifies that the UUT uses a maximum ± 1 sample pulse leading edge position tolerance using P1 and P3. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
6. *Input N sets up a preamble where only P1 and P3 have actual leading edges, while P2 and P4 will have pulse positions provided by the extended P1 and P3 pulses. The P3 leading edge position is offset by +0.2 microseconds. This test input step verifies that the UUT uses a maximum ± 1 sample pulse leading edge position tolerance using P1 and P3. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
7. *Input O sets up a preamble where only P1 and P4 have actual leading edges, while P2 and P3 will have pulse positions provided by the extended P1 pulse. The P4 leading edge position is offset by -0.2 microseconds. This test input step verifies that the UUT uses a maximum ± 1 sample pulse leading edge position tolerance using P1 and P4. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
8. *Input P sets up a preamble where only P1 and P4 have actual leading edges, while P2 and P3 will have pulse positions provided by the extended P1 pulse. The P4 leading edge position is offset by +0.2 microseconds. This test input step verifies that the UUT uses a maximum ± 1 sample pulse leading edge position tolerance using P1 and P4. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*

9. *The purpose of Input Q is to test that the UUT does not simultaneously apply both a + and – sample tolerance. Input Q sets up a preamble with no actual preamble pulse leading edges in their nominal positions. The P1 position is offset by -0.3 microseconds and width is offset by +1.3 microseconds to replace the missing P2 pulse. This places the P1 and P2 actual leading edges out of detection range but provides pulse positions at nominal positions. This focuses the actual leading edge detection on P3 and P4 whose leading edges are offset by -0.125 microseconds and +0.125 microseconds respectively. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
10. *The purpose of Input R is to test that the UUT does not simultaneously apply both a + and – sample tolerance. Input R sets up a preamble with no actual preamble pulse leading edges in their nominal positions. The P1 position is offset by -0.3 microseconds and width is offset by +1.3 microseconds to replace the missing P2 pulse. This places the P1 and P2 actual leading edges out of detection range but provides pulse positions at nominal positions. This focuses the actual leading edge detection on P3 and P4 whose leading edges are offset by +0.125 microseconds and -0.125 microseconds respectively. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
11. *The purpose of Input S is to test that the UUT does not simultaneously apply both a + and – sample tolerance. Input S sets up a preamble with no actual preamble pulse leading edges in their nominal positions. The P1 and P3 positions are offset by -0.3 microseconds and widths are offset by +0.3 microseconds. This places the P1 and P3 actual leading edges out of detection range but provides pulse positions at nominal positions. This focuses the actual leading edge detection on P2 and P4 whose leading edges are offset by -0.125 microseconds and +0.125 microseconds respectively. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
12. *The purpose of Input T is to test that the UUT does not simultaneously apply both a + and – sample tolerance. Input T sets up a preamble with no actual preamble pulse leading edges in their nominal positions. The P1 and P3 positions are offset by -0.3 microseconds and widths are offset by +0.3 microseconds. This places the P1 and P3 actual leading edges out of detection range but provides pulse positions at nominal positions. This focuses the actual leading edge detection on P2 and P4 whose leading edges are offset by +0.125 microseconds and -0.125 microseconds respectively. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
13. *The purpose of Input U is to test that the UUT does not simultaneously apply both a + and – sample tolerance. Input U sets up a preamble with no actual preamble pulse leading edges in their nominal positions. The P1 position is offset by -0.3 microseconds and width is offset by +0.3 microseconds. The P3 width is offset by +1.0 microsecond to replace the missing P4 pulse. This places the P1 and P4 actual leading edges out of detection range but provides pulse positions at nominal positions. This focuses the actual leading edge detection on P2 and P3 whose leading edges are offset by -0.125 microseconds and +0.125 microseconds respectively. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
14. *The purpose of Input V is to test that the UUT does not simultaneously apply both a + and – sample tolerance. Input V sets up a preamble with no actual preamble pulse leading edges in their nominal positions. The P1 position is offset by -0.3 microseconds and width is offset by +0.3 microseconds. The P3 width is offset by +1.0 microsecond to replace the missing P4 pulse. This places the P1 and P4 actual leading edges out of detection range but provides pulse positions at nominal positions. This focuses the actual leading edge detection on P2 and P3 whose leading edges are offset by +0.125 microseconds and -0.125 microseconds respectively. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*
15. *Input W verifies that the UUT requires all 4 preamble pulses to be present. This test step will be repeated 3 times with each preamble pulse taking a turn as the missing pulse. This is a negative test procedure and requires that the UUT accepts this input at a rate of 10% or less.*

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level is adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures is lowered by 3 dB.

Step 1: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 1

Apply **Input A** at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 2: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 2

Repeat Step 1 with the signal power level at -65 dBm.

Step 3: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 3

Apply **Input B** at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 4: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 4

Repeat Step 3 with the signal power level at -65 dBm.

Step 5: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 5

Apply Input C at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 6: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 6

Repeat Step 5 with the signal power level at -65 dBm.

Step 7: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 7

Apply Input D at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 8: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 8

Repeat Step 7 with the signal power level at -65 dBm.

Step 9: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 9

Apply Input E at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 10: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 10

Repeat Step 9 with the signal power level at -65 dBm.

Step 11: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 11

Apply Input F at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 12: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 12

Repeat Step 11 with the signal power level at -65 dBm.

Step 13: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 13

Apply Input G at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 14: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 14

Repeat Step 13 with the signal power level at -65 dBm.

Step 15: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 15

Apply Input H at the receiver input and verify that at least 90 percent of the ADS-B Messages are correctly decoded.

Step 16: Preamble Pulse Characteristics set to the Extreme Limits of their Tolerance Range - Part 16

Repeat Step 15 with the signal power level at -65 dBm.

Step 17: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 1

Apply Input I at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 18: Preamble Pulse Widths set to Out-of-Tolerance Values - Part 2

Repeat Step 17 with the signal power level at -65 dBm.

Step 19: Preamble Single Pulse - Part 1

Apply Input J at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 20: Preamble Single Pulse - Part 2

Repeat Step 19 with the signal power level at -65 dBm.

Step 21: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 1

Apply Input K at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 22: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 2

Repeat Step 21 with the signal power level at -65 dBm.

Step 23: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 3

Apply Input L at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 24: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 4

Repeat Step 23 with the signal power level at -65 dBm.

Step 25: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 5

Apply Input M at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 26: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 6

Repeat Step 25 with the signal power level at -65 dBm.

Step 27: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 7

Apply Input N at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 28: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 8

Repeat Step 27 with the signal power level at -65 dBm.

Step 29: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 9

Apply Input O at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 30: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 10

Repeat Step 29 with the signal power level at -65 dBm.

Step 31: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 11

Apply Input P at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 32: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 12

Repeat Step 31 with the signal power level at -65 dBm.

Step 33: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 13

Apply Input Q at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 34: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 14

Repeat Step 33 with the signal power level at -65 dBm.

Step 35: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 15

Apply Input R at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 36: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 16

Repeat Step 35 with the signal power level at -65 dBm.

Step 37: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 17

Apply Input S at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 38: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 18

Repeat Step 37 with the signal power level at -65 dBm.

Step 39: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 19

Apply Input T at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 40: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 20

Repeat Step 39 with the signal power level at -65 dBm.

Step 41: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 21

Apply Input U at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 42: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 22

Repeat Step 41 with the signal power level at -65 dBm.

Step 43: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 23

Apply Input V at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 44: Preamble Pulse Positions set to Out-of-Tolerance Values - Part 24

Repeat Step 43 with the signal power level at -65 dBm.

Step 45: Missing Preamble Pulse - Part 1

Apply Input W at the receiver input and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 46: Missing Preamble Pulse - Part 2

Repeat Step 45 with the signal power level at -65 dBm.

Step 47: Missing Preamble Pulse - Part 3

Apply Input W at the receiver input except restore the P1 pulse and remove the P2 pulse and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 48: Missing Preamble Pulse - Part 4

Repeat Step 47 with the signal power level at -65 dBm.

Step 49: Missing Preamble Pulse - Part 5

Apply Input W at the receiver input except restore the P1 pulse and remove the P3 pulse and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 50: Missing Preamble Pulse - Part 6

Repeat Step 49 with the signal power level at -65 dBm.

Step 51: Missing Preamble Pulse - Part 7

Apply Input W at the receiver input except restore the P1 pulse and remove the P4 pulse and verify that no more than 10 percent of the ADS-B Messages are correctly decoded.

Step 52: Missing Preamble Pulse - Part 8

Repeat Step 51 with the signal power level at -65 dBm.

2.4.4.4.2.3 Preamble Validation Tests

Purpose/Introduction:

These tests verify that the ADS-B reply processor correctly validates the ADS-B preamble. It is verified that when energy with an amplitude within 6 dB of the preamble reference level is contained in at least one chip of the first five data bits, the preamble is accepted, and the preamble is rejected if one or more of the first five data bits has insufficient energy in either chip.

Reference Input:

Provide a method of supplying the UUT with:

Any Valid ADS-B Message having:

"DF"	=	17 (or 18 as indicated in the test procedures)
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	50 Hz
Frequency	=	1090 MHz
Power	=	-23 dBm

The transmitted power in the first six data bits is controlled in such a way that the amplitude of a data bit can be set independently of the others.

Measurement Procedure:

The ADS-B receiver power levels specified in this procedure are relative to the loss at the RF message source end of the transmission line used to interface the RF message source to the UUT receiver input port. For each ADS-B equipage class, the specified power level is adjusted to compensate for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures is lowered by 3 dB.

For this test to be valid the receiver must perform error correction.

Step 1: Preamble Validation – Missing First Data Bit - Part 1

Input the **Reference Input** DF=17 messages with the amplitude of the first data bit set to –30 dB into the receiver, and verify that less than 10 percent of the ADS-B Messages are correctly decoded.

Step 2: Preamble Validation – Missing First Data Bit - Part 2

Repeat Step 1 with the signal power level at -65 dBm and the first bit at –72 dBm.

Step 3: Preamble Validation – Missing Second Data Bit - Part 1

Input the **Reference Input** DF=17 messages with the amplitude of the second data bit set to –30 dBm into the receiver and verify that less than 10 percent of the ADS-B Messages are correctly decoded.

Step 4: Preamble Validation – Missing Second Data Bit - Part 2

Repeat Step 3 with the signal power level at -65 dBm and the second bit at –72 dBm.

Step 5: Preamble Validation – Missing Third Data Bit - Part 1

Input the **Reference Input** DF=17 messages with the amplitude of the third data bit set to –30 dBm into the receiver and verify that less than 10 percent of the ADS-B Messages are correctly decoded.

Step 6: Preamble Validation – Missing Third Data Bit - Part 2

Repeat Step 5 with the signal power level at -65 dBm and the third bit at –72 dBm.

Step 7: Preamble Validation – Missing Third and Fourth Data Bit - Part 1

Input the **Reference Input** DF=17 messages with the amplitude of the third data pulse (that comprises the third and fourth data bits) set to –30 dBm into the receiver and verify that less than 10 percent of the ADS-B Messages are correctly decoded.

Step 8: Preamble Validation – Missing Third and Fourth Data Bit - Part 2

Repeat Step 7 with the signal power level at -65 dBm and the third data pulse at –72 dBm.

Step 9: Preamble Validation – Missing Fourth and Fifth Data Bit - Part 1

Input the **Reference Input** DF=17 messages with the amplitude of the fourth data pulse (that comprises the fourth and fifth data bits) set to –30 dBm into the receiver and verify that less than 10 percent of the ADS-B Messages are correctly decoded.

Step 10: Preamble Validation – Missing Fourth and Fifth Data Bit - Part 2

Repeat Step 9 with the signal power level at -65 dBm and the fourth data pulse at –72 dBm.

Step 11: Preamble Validation – Missing Sixth Data Bit - Part 1

Input the **Reference Input** DF=17 messages with no energy in either chip of the sixth data bit into the receiver and verify that greater than 90 percent of the ADS-B Messages are correctly decoded.

Step 12: Preamble Validation – Missing Sixth Data Bit - Part 2

Repeat Step 11 with the signal power level at -65 dBm.

2.4.4.4.2.4 Combined Preamble and Data Block Tests with Mode A/C FRUIT

Purpose/Introduction:

The following tests measure the performance of the equipment under test in decoding the Extended Squitter preamble and data block overlapped with Mode A/C FRUIT. The test series begins with monitoring the reception performance in the absence of interference to establish that the equipment under test is operating correctly.

Next, a series of tests are conducted with the number of Mode A/C FRUIT overlaps set to one to five respectively for A2 and A3 equipment class. For A1S and A1 equipment class, the tests are limited to a maximum of three Mode A/C FRUIT overlaps. For each test, the timing of the overlapping FRUIT is uniformly pseudo randomly distributed across the preamble and data block for seven different relative power levels. The FRUIT power levels will be set according to the test step being conducted and will remain constant while each of the seven Extended Squitter power levels are tested. **T** samples (§2.4.4.4.2.1) are taken at each power level. Squitters that are declared to be correctly received (i.e., received without errors or successfully error corrected) are compared to the known content of the Extended Squitter transmission. Any difference between the content of the decoded Extended Squitter and the known content of the injected squitter is recorded as an undetected error and that squitter reception is removed from the count of successfully received squitters.

The observed probability of correct squitter reception for each relative power level is computed. An average value of the performance across all power levels is computed and compared to the required performance to determine success or failure for the test.

Step 1: Verification of Operation of Equipment Under Test

Connect the Extended Squitter signal source and set the power level at the receiver input equal to the MTL limit required for the UUT equipment class:

–79 dBm for A1S and A1 equipment class or,

–79 dBm for A2 equipment class or,

–84 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Inject the Extended Squitter signal **T** times (§2.4.4.4.2.1) and record the Extended Squitters that are declared to be output as error free. Compare the decoded content of each Extended Squitter with the known content of the injected Extended Squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 90% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2: Test with One Mode A/C Fruit Overlap

Set the Extended Squitter signal source as specified in Step 1.

Set the power level of one Mode A/C FRUIT source at the receiver input to the value corresponding to the UUT equipment class:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Activate the Mode A/C FRUIT source so that the FRUIT is pseudo randomly distributed across the Extended Squitter preamble and data block as specified in §2.4.4.4.2.1.

Inject the Extended Squitter waveform **T** times (§2.4.4.4.2.1) and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step six times while increasing the Extended Squitter power level by 4 dB with each iteration.

Calculate the average probability of reception and the total number of undetected errors across the seven power levels.

Step 3: Test with Two Mode A/C Fruit Overlaps

Repeat Step 2 with two FRUIT overlaps set to the following power levels and record the results:

-69 and –65 dBm for A1S, A1 or A2 equipment class or,

-74 and –70 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Step 4: Test with Three Mode A/C Fruit Overlaps

Repeat Step 2 with three FRUIT overlaps set to the following power levels and record the results:

-71, -67 and –63 dBm for A1S, A1 or A2 equipment class or,

-76, -72 and –68 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Step 5: Test with Four Mode A/C Fruit Overlaps

Repeat Step 2 with four FRUIT overlaps set to the following power levels and record the results:

-73, -69, -65 and –61 dBm for A2 equipment class or,

-78, -74, -70 and –66 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Step 6: Test with Five Mode A/C Fruit Overlaps

Repeat Step 2 with five FRUIT overlaps set to the following power levels and record the results:

-75, -71, -67, -63 and –59 dBm for A2 equipment class or,

-80, -76, -72, -68 and –64 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Step 7: Determination of Success or Failure

Compare the results recorded above with the appropriate requirements in Table 2-157, Table 2-158 or Table 2-159.

Table 2-157: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A1S and A1 Equipment

Number of Fruit	**1**	**2**	**3**
Minimum Probability	0.89	0.64	0.52
Max Undetected Errors	1	1	1

Table 2-158: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A2 Equipment

Number of Fruit	**1**	**2**	**3**	**4**	**5**
Minimum Probability	0.93	0.89	0.88	0.79	0.74
Max Undetected Errors	1	1	1	1	1

Table 2-159: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A3 Equipment

Number of Fruit	**1**	**2**	**3**	**4**	**5**
Minimum Probability	0.94	0.91	0.90	0.86	0.85
Max Undetected Errors	1	1	1	1	1

2.4.4.4.2.5 Data Block Tests with Mode S Fruit

Purpose/Introduction:

The following tests measure the performance of the equipment under test in decoding the Extended Squitter data content overlapped with Mode S FRUIT. The test series begins with monitoring the reception performance in the absence of interference to establish that the equipment under test is operating correctly.

Next, a test is conducted with a single Mode S FRUIT overlap. For this test, the timing of the overlapping FRUIT is uniformly pseudo randomly distributed across the data block for four different relative power levels. **T** samples (§2.4.4.4.2.1) are taken at each power level. Squitters that are declared to be correctly received (i.e., received without errors or successfully error corrected) are compared to the known content of the Extended Squitter transmission. Any difference between the content of the decoded Extended Squitter and the known content of the injected squitter is recorded as an undetected error and that squitter reception is removed from the count of successfully received squitters.

Finally, the observed probability of correct squitter reception for each relative power level is computed.

Step 1: Verification of Operation of Equipment Under Test

Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Inject the signal **T** times (§2.4.4.4.2.1) and record the Extended Squitters that are declared to be output as error free. Compare the decoded content of each Extended Squitter with the known content of the injected Extended Squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 95% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2: Test with One Mode S Fruit Overlap

Set the Extended Squitter signal source as specified in Step 1.

Activate the Mode S FRUIT source so that the Mode S FRUIT is pseudo randomly distributed across the data Extended Squitter data block as specified in §2.4.4.4.2.1.2.

Set the Extended Squitter power to 0 dB relative to the Mode S FRUIT signal level.

Inject the Extended Squitter waveform **T** times (§2.4.4.4.2.1) and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of signal to interference (S/I) of +4, +8, and + 12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the four power levels.

Step 3: Determination of Success or Failure

Compare the results recorded above with the appropriate requirements in Table 2-160, Table 2-161 or Table 2-162.

Table 2-160: Success Criteria for Data Block Tests with Mode S Fruit – Class A1S and A1 Equipment

Relative Power (S/I) dB	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**	**+8**	**+12**
Minimum Probability	0	0	0.02	0.12	0.56	0.71	0.94	0.95	0.99	0.99
Max Undetected Errors	1	1	1	1	1	1	1	1	1	1

Table 2-161: **Success Criteria for Data Block Tests with Mode S Fruit – Class A2 Equipment**

Relative Power (S/I) dB	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**	**+8**	**+12**
Minimum Probability	0	0	0.02	0.12	0.59	0.8	0.95	0.99	0.99	0.99
Max Undetected Errors	1	1	1	1	1	1	1	1	1	1

Table 2-162: **Success Criteria for Data Block Tests with Mode S Fruit – Class A3 Equipment**

Relative Power (S/I) dB	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**	**+8**	**+12**
Minimum Probability	0	0	0.02	0.12	0.59	0.8	0.95	0.99	0.99	0.99
Max Undetected Errors	1	1	1	1	1	1	1	1	1	1

2.4.4.4.2.6 Re-Triggering Performance

Purpose/Introduction:

The following tests measure the capability of the equipment under test to detect Extended Squitters that are preceded by lower level Mode S FRUIT. The test series begins with monitoring the reception performance in the absence of interference to establish that the equipment under test is operating correctly.

Next, a test is conducted with a single Mode S FRUIT overlap with a varying position. For this test, the timing of the overlapping FRUIT is uniformly pseudo randomly distributed across the time interval beginning at –112 microseconds and ending at –6 microseconds relative to the leading edge of the P1 preamble pulse of the Extended Squitter.

Finally, a test is conducted with a single Mode S FRUIT overlap with a fixed position. For this test, the timing of the overlapping FRUIT is fixed at –6 microseconds relative to the leading edge of the P1 preamble pulse of the Extended Squitter.

The re-triggering performance tests are conducted at three different relative power levels. **T** samples (§2.4.4.4.2.1) are taken at each power level. Squitters that are declared to have been correctly received (i.e., received without errors or successfully error corrected) are compared to the known content of the Extended Squitter transmission. Any difference between the content of the decoded Extended Squitter and the known content of the injected squitter is recorded as an undetected error and that squitter reception is removed from the count of successfully received squitters. The observed probability of correct squitter reception for each relative power level is computed.

Step 1: Verification of Operation of Equipment Under Test

Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Inject the signal **T** times (§2.4.4.4.2.1) and record the Extended Squitters that are declared to be output as error free. Compare the decoded content of each Extended Squitter with the known content of the injected Extended Squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 95% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2: Re-triggering Test with Varying Position Mode S Fruit

Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Set the Extended Squitter power to +4 dB relative to the Mode S FRUIT signal level.

Activate the Mode S FRUIT source so that the 112-bit Mode S FRUIT signal is uniformly randomly distributed across the time interval beginning at –112 microseconds and ending at –6 microseconds relative to the signal. The time indicated is the spacing between the P1 pulse of the signal and the P1 pulse of the FRUIT, where negative values indicate that the FRUIT is received earlier.

Inject the Extended Squitter waveform **T** times (§2.4.4.4.2.1) and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1.

Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of Signal to Interference (S/I) of +8, and + 12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the three power levels.

Compare the results recorded above with the appropriate requirements in Table 2-163, Table 2-164 or Table 2-165.

Table 2-163: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A1S and A1 Equipment

Relative Power, (S/I) dB	**+4**	**+8**	**+12**
Minimum Probability	0.12	0.70	0.91
Max Undetected Errors	1	1	1

Table 2-164: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A2 Equipment

Relative Power, (S/I) dB	**+4**	**+8**	**+12**
Minimum Probability	0.12	0.88	0.94
Max Undetected Errors	1	1	1

Table 2-165: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A3 Equipment

Relative Power, (S/I) dB	**+4**	**+8**	**+12**
Minimum Probability	0.12	0.88	0.94
Max Undetected Errors	1	1	1

Step 3: Re-triggering Test with Fixed Position Mode S Fruit

Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1S, A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Note: *The power levels given above are specified at the antenna connector and not at the receiver unit-under-test connector.*

Set the Extended Squitter power to +4 dB relative to the Mode S FRUIT signal level.

Activate the Mode S FRUIT source so that the 112-bit Mode S FRUIT signal has a fixed time 6 microseconds earlier than the signal. The 6-microsecond time is the spacing between the P1 pulse of the Mode S FRUIT and the P1 pulse of the signal.

Inject the Extended Squitter waveform **T** times (§2.4.4.4.2.1) and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of Signal to Interference (S/I) of +8, and +12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the three power levels.

Compare the results recorded above with the appropriate requirements in Table 2-166, Table 2-167 or Table 2-168.

Table 2-166: Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – Class A1S and A1 Equipment

Relative Power, (S/I) dB	**+4**	**+8**	**+12**
Minimum Probability	0	0.49	0.87
Max Undetected Errors	1	1	1

Table 2-167: Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – Class A2 Equipment

Relative Power, (S/I) dB	**+4**	**+8**	**+12**
Minimum Probability	0.26	0.93	0.94
Max Undetected Errors	1	1	1

Table 2-168: Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – Class A3 Equipment

Relative Power, (S/I) dB	+4	+8	+12
Minimum Probability	0.26	0.93	0.94
Max Undetected Errors	1	1	1

2.4.4.4.3 Verification of Error Correction (§2.2.4.4.3)

2.4.4.4.3.1 Verification of Error Correction Requirements (§2.2.4.4.3.1)

Purpose/Introduction:

ADS-B Receiving Subsystems either:

a. use "conservative" and "brute force" error correction techniques as defined in §I.4.3, or

b. use alternative error correction techniques that are demonstrated to provide no more than 1 x (10^{-6}) report error rate.

Measurement Procedures:

An analysis of the hardware/software design may be performed showing that conservative and brute force error correction techniques have been used, or that the alternative techniques meet the required undetected report error rate.

2.4.4.4.3.2 Verification of Error Correction Restrictions (§2.2.4.4.3.2)

Purpose/Introduction:

This test verifies that the sliding window error correction technique, which is used in TCAS, is not being used in the unit under test. In lieu of this test procedure, an analysis of the hardware/software design may be performed showing that a sliding window error correction technique is not used.

To carry out this test, it is necessary to introduce several low-confidence flags (see Figure 2-33) for which the corresponding information bit is incorrect in some case and in other cases low-confidence flags for which the corresponding bit is correct. Introducing such errors and flags may be done in different ways for different receiver designs. Given that the implementation specifics for enhanced reception are not rigidly standardized (whereas the reception performance is standardized), the specific means for introducing the bit errors and flags is implementation dependent.

Note: *See Appendix I, §I.3.3 and §I.4.3 for more details on error correcting techniques.*

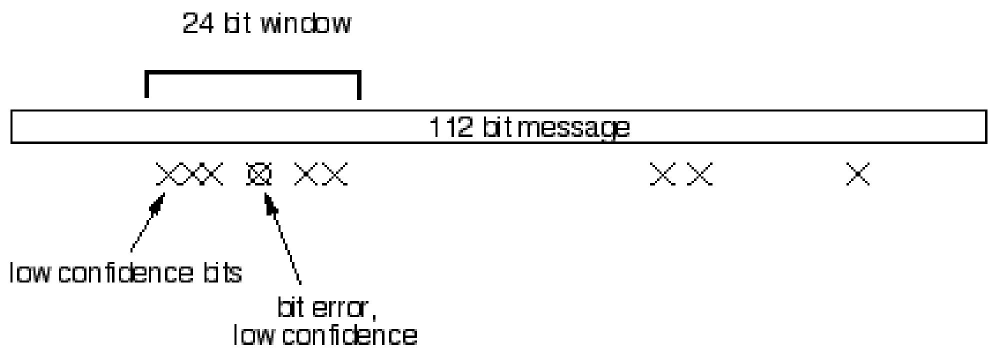


Figure 2-33: Bit Error and Low Confidence Flags

Equipment Required:

Provide a method of supplying the unit under test with any valid ADS-B Message having:

"DF"	=	17
"CA"	=	0
"AA"	=	Any discrete address
Message Rate	=	1 Hz
Frequency	=	1090 MHz
Power	=	-50 dBm

Also provide an interference generator that can generate multiple interference pulses, in order to introduce bit errors and low confidence flags.

Measurement Procedure:

Step 1: Verification of Operation of Equipment Under Test

Apply tha ADS-B Input Message without interference. Verify that there is at least 99% correct reception.

Step 2: Test with Low Confidence Flags

Add interfering pulses in a way that introduces six (6) low-confidence flags within a 24-microsecond window and three (3) additional low-confidence flags away from the 24-microsecond window. The 24-microsecond window begins with the first low-confidence flag. For the six affected bits in 24-microseconds, one is to have a bit error, and the other five are to have correct bit declaration. For the three bits away from the 24-microsecond window, all three are to have correct bit declaration. Verify that the message is not accepted under this condition.

2.4.4.5 Verification of ADS-B Received Message Error Protection (§2.2.4.5)

Appropriate test procedures to verify the requirements of §2.2.4.5 are provided in §2.4.4.3.4.7.3.

2.4.5 Verification of ADS-B Transmission Device Message Processor Characteristics (§2.2.5)

No specific test procedures are required to validate §2.2.5.

2.4.5.1 Verification of ADS-B Transmission Device Data Processing and Message Formatting (§2.2.5.1)

No specific test procedure is required to validate §2.2.5.1.

2.4.5.1.1 Verification of the Participant Address (§2.2.5.1.1)

No specific test procedure is required to validate §2.2.5.1.1.

2.4.5.1.1.1 Verification of the ICAO 24-Bit Address (§2.2.5.1.1.1)

Appropriate test procedures required to validate the requirements of §2.2.5.1.1.1 were previously provided in §2.4.3.2.1.7 during verification of the “PI” field.

2.4.5.1.1.2 Verification of the Anonymous Address (§2.2.5.1.1.2)

Appropriate test procedures required to validate the requirements of §2.2.5.1.1.2 were previously provided in §2.4.3.2.1.5 during verification of the “AA” field for Non-Transponder Devices.

2.4.5.1.1.3 Verification of the Address Qualifier for Non-Transponder Devices (§2.2.5.1.1.3)

Appropriate test procedures required to validate the requirements of §2.2.5.1.1.3 were previously provided in §2.4.3.2.1.5 during verification of the “AA” field for Non-Transponder Devices.

2.4.5.1.2 Verification of ADS-B Emitter Category Data (§2.2.5.1.2)

Appropriate test procedures required to validate the requirements of §2.2.5.1.2 were previously provided in §2.4.3.2.5.2 during verification of the Emitter Category Data in the Aircraft Identification and Category Message.

2.4.5.1.3 Verification of Air/Ground Status Data (§2.2.5.1.3)

Appropriate test procedures required to validate the requirements of §2.2.5.1.3 were previously provided in §2.4.3.2.1.2 through §2.4.3.2.1.2.2 during verification of the “CA” field.

2.4.5.1.4 Verification of Surveillance Status Data (§2.2.5.1.4)

Appropriate test procedures required to validate the requirements of §2.2.5.1.4 were previously provided in §2.4.3.2.3.2 during verification of "Surveillance Status" in the Airborne Position Message.

2.4.5.1.5 Verification of Altitude Data (§2.2.5.1.5)

Appropriate test procedures required to validate the requirements of §2.2.5.1.5 were previously provided in §2.4.3.2.3.4 through §2.4.3.2.3.4.3 during verification of Altitude data provided in the Airborne Position Message.

2.4.5.1.6 Verification of Time Data and Time Mark Pulse (§2.2.5.1.6)

No specific test procedure is required to validate the requirements of §2.2.5.1.6.

2.4.5.1.6.1 Verification of Case, where TIME ("T") = 0 (§2.2.5.1.6.1)

Appropriate test procedures required to validate the requirements of §2.2.5.1.6.1 were previously provided in §2.4.3.2.3.5, §2.4.3.2.3.7.2.2 and §2.4.3.2.3.8.2.2 for the Airborne Position Message and §2.4.3.2.4.5, §2.4.3.2.4.7.2.2 and §2.4.3.2.4.8.2.2 for the Surface Position Message.

2.4.5.1.6.2 Verification of Case, where TIME ("T") = 1 (§2.2.5.1.6.2)

Appropriate test procedures required to validate the requirements of §2.2.5.1.6.2 were previously provided in §2.4.3.2.3.5, §2.4.3.2.3.7.2.1 and §2.4.3.2.3.8.2.1 for the Airborne Position Message and §2.4.3.2.4.5, §2.4.3.2.4.7.2.1 and §2.4.3.2.4.8.2.1 for the Surface Position Message.

2.4.5.1.7 Verification of Own Position Latitude Data (§2.2.5.1.7)

Appropriate test procedures required to validate the requirements of §2.2.5.1.7 were previously provided in §2.4.3.2.3.7.1 through §2.4.3.2.3.7.4 for the Airborne Position Message and §2.4.3.2.4.7.1 through §2.4.3.2.4.7.4 for the Surface Position Message.

2.4.5.1.8 Verification of Own Position Longitude Data (§2.2.5.1.8)

Appropriate test procedures required to validate the requirements of §2.2.5.1.8 were previously provided in §2.4.3.2.3.8.1 through §2.4.3.2.3.8.4 for the Airborne Position Message and §2.4.3.2.4.8.1 through §2.4.3.2.4.8.4 for the Surface Position Message.

2.4.5.1.9 Verification of Ground Speed Data (§2.2.5.1.9)

Appropriate test procedures required to validate the requirements of §2.2.5.1.9 were previously provided in §2.4.3.2.4.2 during verification of the "Movement" subfield in the Surface Position Message.

2.4.5.1.10 Verification of Heading/Ground Track Data (§2.2.5.1.10)

Appropriate test procedures required to validate the requirements of §2.2.5.1.10 were previously provided in §2.4.3.2.4.3 and §2.4.3.2.4.4 during verification of Heading/Ground Track information provided in the Surface Position Message.

2.4.5.1.11 Verification of Aircraft Identification (*or* Registration) Data (§2.2.5.1.11)

Appropriate test procedures required to validate the requirements of §2.2.5.1.11 were previously provided in §2.4.3.2.5.3 during verification of Character information provided in the Aircraft Identification and Category Message.

2.4.5.1.12 Verification of East/West Velocity Data (§2.2.5.1.12)

Appropriate test procedures required to validate the requirements of §2.2.5.1.12 were previously provided in §2.4.3.2.6.1.6 and §2.4.3.2.6.1.7 for Subtype=1 Velocity Messages and in §2.4.3.2.6.2.6 and §2.4.3.2.6.2.7 for Subtype=2 Velocity Messages.

2.4.5.1.13 Verification of North/South Velocity Data (§2.2.5.1.13)

Appropriate test procedures required to validate the requirements of §2.2.5.1.13 were previously provided in §2.4.3.2.6.1.8 and §2.4.3.2.6.1.9 for Subtype=1 Velocity Messages and in §2.4.3.2.6.2.8 and §2.4.3.2.6.2.9 for Subtype=2 Velocity Messages.

2.4.5.1.14 Verification of Vertical Rate Data (§2.2.5.1.14)

Appropriate test procedures required to validate the requirements of §2.2.5.1.14 were previously provided in §2.4.3.2.6.1.10 and §2.4.3.2.6.1.11 for Subtype=1 Velocity Messages and in §2.4.3.2.6.2.10 and §2.4.3.2.6.2.11 for Subtype=2 Velocity Messages.

2.4.5.1.15 Verification of Heading Data (§2.2.5.1.15)

Appropriate test procedures required to validate the requirements of §2.2.5.1.15 were previously provided in §2.4.3.2.6.3.6 and §2.4.3.2.6.3.7 for Subtype=3 and "4" Velocity Messages.

2.4.5.1.16 Verification of True Airspeed Data (§2.2.5.1.16)

Appropriate test procedures required to validate the requirements of §2.2.5.1.16 were previously provided in §2.4.3.2.6.3.8 and §2.4.3.2.6.3.9 for Subtype=3 Velocity Messages and §2.4.3.2.6.4.8 and §2.4.3.2.6.4.9 for Subtype=4 Velocity Messages.

2.4.5.1.17 Verification of Indicated Airspeed Data (§2.2.5.1.17)

Appropriate test procedures required to validate the requirements of §2.2.5.1.17 were previously provided in §2.4.3.2.6.3.8 and §2.4.3.2.6.3.9 for Subtype=3 Velocity Messages and §2.4.3.2.6.4.8 and §2.4.3.2.6.4.9 for Subtype=4 Velocity Messages.

2.4.5.1.18 Verification of Intent Change Data (§2.2.5.1.18)

Appropriate test procedures required to validate the requirements of §2.2.5.1.18 were previously provided in §2.4.3.2.6.1.3 for Subtype=1 through "4" Velocity Messages.

2.4.5.1.19 Verification of NAC_V Data (§2.2.5.1.19)

Appropriate test procedures required to validate the requirements of §2.2.5.1.19 were previously provided in §2.4.3.2.6.1.5 for Subtype=1 through "4" Velocity Messages.

2.4.5.1.20 Verification of Subtype (Aircraft Status) Data (§2.2.5.1.20)

Appropriate test procedures required to validate the requirements of §2.2.5.1.20 were previously provided in §2.4.3.2.7.2.2.

2.4.5.1.21 Verification of Capability Class (Reserved) Data (§2.2.5.1.21)

Appropriate test procedures required to validate the requirements of §2.2.5.1.21 were previously provided in §2.4.3.2.7.2.3.1.

2.4.5.1.22 Verification of Capability Class (UAT IN) Data (§2.2.5.1.22)

Appropriate test procedures required to validate the requirements of §2.2.5.1.22 were previously provided in §2.4.3.2.7.2.3.10.

2.4.5.1.23 Verification of Capability Class (1090ES IN) Data (§2.2.5.1.23)

Appropriate test procedures required to validate the requirements of §2.2.5.1.23 were previously provided in §2.4.3.2.7.2.3.3.

2.4.5.1.24 Verification of Capability Class (ARV Report Capability) Data (§2.2.5.1.24)

Appropriate test procedures required to validate the requirements of §2.2.5.1.24 were previously provided in §2.4.3.2.7.2.3.4.

2.4.5.1.25 Verification of Capability Class (TS Report Capability) Data (§2.2.5.1.25)

Appropriate test procedures required to validate the requirements of §2.2.5.1.25 were previously provided in §2.4.3.2.7.2.3.5.

2.4.5.1.26 Verification of Capability Class (TC Report Capability) Data (§2.2.5.1.26)

Appropriate test procedures required to validate the requirements of §2.2.5.1.26 were previously provided in §2.4.3.2.7.2.3.6.

2.4.5.1.27 Verification of Capability Class (Position Offset Applied) Data (§2.2.5.1.27)

Appropriate test procedures required to validate the requirements of §2.2.5.1.27 were previously provided in §2.4.3.2.7.2.3.7.

2.4.5.1.28 Verification of Operational Mode (OM Format) Data (§2.2.5.1.28)

Appropriate test procedures required to validate the requirements of §2.2.5.1.28 were previously provided in §2.4.3.2.7.2.4.1.

2.4.5.1.29 Verification of Operational Mode (TCAS/ACAS Resolution Advisory Active) Data (§2.2.5.1.29)

Appropriate test procedures required to validate the requirements of §2.2.5.1.29 were previously provided in §2.4.3.2.7.2.4.2.

2.4.5.1.30 Verification of Operational Mode (IDENT Switch Active) Data (§2.2.5.1.30)

Appropriate test procedures required to validate the requirements of §2.2.5.1.30 were previously provided in §2.4.3.2.7.2.4.3.

2.4.5.1.31 Verification of Operational Mode (Reserved for Receiving ATC Services) Data (§2.2.5.1.31)

Appropriate test procedures required to validate the requirements of §2.2.5.1.31 were previously provided in §2.4.3.2.7.2.4.4.

2.4.5.1.32 Verification of the Radio Altitude Data (§2.2.5.1.32)

Appropriate test procedures required to validate the requirements of §2.2.5.1.32 were previously provided in §2.4.3.2.1.2.

2.4.5.1.33 Verification of the Version Number Data (§2.2.5.1.33)

Appropriate test procedures required to validate the requirements of §2.2.5.1.33 were previously provided in §2.4.3.2.7.2.5.

2.4.5.1.34 Verification of Navigation Accuracy Category for Position (NAC_P) Data (§2.2.5.1.34)

Appropriate test procedures required to validate the requirements of §2.2.5.1.34 were previously provided in §2.4.3.2.7.1.3.8 and §2.4.3.2.7.2.7.

2.4.5.1.35 Verification of Navigation Integrity Category for Barometric Altitude (NIC_{BARO}) Data (§2.2.5.1.35)

Appropriate test procedures required to validate the requirements of §2.2.5.1.35 were previously provided in §2.4.3.2.7.1.3.9 and §2.4.3.2.7.2.10.

2.4.5.1.36 Verification of Navigation Integrity Category Supplement (NIC_{SUPP}) Data (§2.2.5.1.36)

Appropriate test procedures required to validate the requirements of §2.2.5.1.36 were previously provided in §2.4.3.2.3.3 and §2.4.3.2.7.2.6.

2.4.5.1.37 Verification of A/V Length/Width Code Data (§2.2.5.1.37)

Appropriate test procedures required to validate the requirements of §2.2.5.1.37 were previously provided in §2.4.3.2.7.2.11.

2.4.5.1.38 Verification of Track Angle/Heading Data (§2.2.5.1.38)

Appropriate test procedures required to validate the requirements of §2.2.5.1.38 were previously provided in §2.4.3.2.7.2.12.

2.4.5.1.39 Verification of Horizontal Reference Direction (HRD) Data (§2.2.5.1.39)

Appropriate test procedures required to validate the requirements of §2.2.5.1.39 were previously provided in §2.4.3.2.7.2.13.

2.4.5.1.40 Verification of Source Integrity Level (SIL) Data (§2.2.5.1.40)

Appropriate test procedures required to validate the requirements of §2.2.5.1.40 were previously provided in §2.4.3.2.7.1.3.10 and §2.4.3.2.7.2.9.

2.4.5.1.41 Verification of SIL Supplement Data (§2.2.5.1.41)

Appropriate test procedures required to validate the requirements of §2.2.5.1.41 were previously provided in §2.4.3.2.7.1.3.1.

2.4.5.1.42 Verification of MCP/FCU Selected Altitude or FMS Selected Altitude Data (§2.2.5.1.42)

Appropriate test procedures required to validate the requirements of §2.2.5.1.42 were previously provided in §2.4.3.2.7.1.3.3.

2.4.5.1.43 Verification of Barometric Pressure Setting (Minus 800 millibars) Data (§2.2.5.1.43)

Appropriate test procedures required to validate the requirements of §2.2.5.1.43 were previously provided in §2.4.3.2.7.1.3.4.

2.4.5.1.44 Verification of Selected Heading Data (§2.2.5.1.44)

Appropriate test procedures required to validate the requirements of §2.2.5.1.44were previously provided in §2.4.3.2.7.1.3.7.

2.4.5.1.45 Verification of MCP/FCU Mode Bits Data (§2.2.5.1.45)

Appropriate test procedures required to validate the requirements of §2.2.5.1.45 were previously provided in §2.4.3.2.7.1.3.11 through §2.4.3.2.7.1.3.16.

2.4.5.1.46 Verification of Emergency/Priority Status Data (§2.2.5.1.46)

Appropriate test procedures required to validate the requirements of §2.2.5.1.46 were previously provided in §2.4.3.2.7.8.1.

2.4.5.1.47 Verification of Mode A (4096) Code Data (§2.2.5.1.47)

Appropriate test procedures required to validate the requirements of §2.2.5.1.47 were previously provided in §2.4.3.2.7.8.1.

2.4.5.1.48 Verification of TCAS Operational Data (§2.4.3.2.7.2.3.2)

Appropriate test procedures required to validate the requirements of §2.2.5.1.48 were previously provided in §2.4.3.2.7.2.3.2.

2.4.5.1.49 Verification of Single Antenna Flag Data (§2.2.3.2.7.2.4.5)

Appropriate test procedures required to validate the requirements of §2.2.5.1.49 were previously provided in §2.4.3.2.7.2.4.5.

2.4.5.1.50 Verification of System Design Assurance (SDA) Data (§2.2.3.2.7.2.4.6)

Appropriate test procedures required to validate the requirements of §2.2.5.1.50 were previously provided in §2.4.3.2.7.2.4.6.

2.4.5.1.51 Verification of GNSS Vertical Figure of Merit (VFOM) Data (§2.2.3.2.7.2.8)

Appropriate test procedures required to validate the requirements of §2.2.5.1.51 were previously provided in §2.4.3.2.7.2.8.

2.4.5.2 ADS-B Transmission Device Message Latency (§2.2.5.2)

No specific test procedure is required to validate the requirements of §2.2.5.2.

2.4.5.2.1 Verification of Airborne Position Message Latency (§2.2.5.2.1)

Purpose/Introduction:

This test verifies the latency of the Airborne Position Message.

Step 1: Airborne Position Message - "TYPE" Subfield (§2.2.3.2.3.1 and §2.2.5.2.1.a)

Purpose/Introduction:

Any change in the TYPE information identified in §2.2.3.2.3.1, or in the NIC Supplement information identified in §2.2.3.2.3.3, **shall** be reflected in the TYPE subfield of the next scheduled Airborne Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non-zero barometric pressure altitude data to the ADS-B System. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged. Verify that the TYPE subfield in the Airborne Position Message correctly matches the TYPE subfield value from the navigational accuracy depicted in Table 2-16.

Change input to the ADS-B System so as to affect the TYPE subfield value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission. Verify that the TYPE subfield value has changed in the next transmitted Airborne Position Message and that it is the correct value.

Change input to the ADS-B System so as to affect the NIC Supplement subfield value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission. Verify that the NIC Supplement subfield value has changed in the next transmitted Airborne Position Message and that it is the correct value.

Step 2: Airborne Position Message – "Surveillance Status" Subfield (§2.2.3.2.3.2 and §2.2.5.2.1.b)

Purpose/Introduction:

Any change in the Surveillance Status identified in §2.2.3.2.3.2 **shall** be reflected in the Surveillance Status subfield of the next scheduled Airborne Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non zero barometric pressure altitude data to the ADS-B System. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged. Verify that the "Surveillance Status" subfield in the Airborne Position Message correctly matches the "Surveillance Status" subfield value from the code definitions depicted in Table 2-17.

Change input to the ADS-B System so as to affect the "Surveillance Status" subfield value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission. Verify that the "Surveillance Status" subfield value has changed in the next transmitted Airborne Position Message and that it is the correct value.

Step 3: Airborne Position Message – "Altitude" Subfield (§2.2.3.2.3.4 and §2.2.5.2.1.c)

Purpose/Introduction:

Any change in the Altitude identified in §2.2.3.2.3.4 **shall** be reflected in the Altitude subfield of the next scheduled Airborne Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non zero barometric pressure altitude data to the ADS-B System. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged. Verify that the "Altitude" subfield in the Airborne Position Message is correct.

Change input to the ADS-B System so as to affect the "Altitude" subfield value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Position Message transmission. Verify that the "Altitude" subfield value has changed in the next transmitted Airborne Position Message and that it is the correct value.

Step 4: Airborne Position Message – "CPR Format" Subfield (§2.2.3.2.3.6 and §2.2.5.2.1.d)

Appropriate test procedures to verify §2.2.5.2.1.d are provided in §2.4.3.2.3.7.2 and §2.4.3.2.3.8.2.

Step 5: Airborne Position Message – "Encoded Latitude" Subfield (§2.2.3.2.3.7 and §2.2.5.2.1.e)

Appropriate test procedures to verify §2.2.5.2.1.e are provided in §2.4.3.2.3.7.2 and §2.4.3.2.3.8.2.

Step 6: Airborne Position Message – "Encoded Longitude" Subfield (§2.2.3.2.3.8 and §2.2.5.2.1.f)

Appropriate test procedures to verify §2.2.5.2.1.f are provided in §2.4.3.2.3.7.2 and §2.4.3.2.3.8.2.

2.4.5.2.2 Verification of Surface Position Message Latency (§2.2.5.2.2)

Purpose/Introduction:

This test verifies the latency of the Surface Position Message.

Step 1: Surface Position Message – "TYPE" Subfield" (§2.2.3.2.4.1 and §2.2.5.2.2.a)

Purpose/Introduction:

Any change in the TYPE information identified in §2.2.3.2.4.1 **shall** be reflected in the TYPE subfield of the next scheduled Surface Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Surface status. Continue transmitting Surface Position Messages at the nominal rate with all parameters unchanged. Verify that the TYPE subfield in the Surface Position Message correctly matches the TYPE subfield value from the navigational accuracy depicted in Table 2-16 for TYPE codes 5, 6, 7 and 8 only.

Change input to the ADS-B System so as to affect the TYPE subfield value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission. Verify that the TYPE subfield value has changed in the next transmitted Surface Position Message and that it is the correct value.

Step 2: Surface Position Message – "Movement" Subfield (§2.2.3.2.4.2 and §2.2.5.2.2.b)

Purpose/Introduction:

Any change in Movement (i.e., Ground Speed) identified in §2.2.3.2.4.2 **shall** be reflected in the Movement subfield of the next scheduled Surface Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Surface status. Continue transmitting Surface Position Messages at the nominal rate with all parameters unchanged. Verify that the Movement subfield in the Surface Position Message correctly matches the Movement subfield value from the Movement subfield Code Definitions in Table 2-18.

Change input to the ADS-B System so as to affect the Movement subfield value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission. Verify that the Movement subfield value has changed in the next transmitted Surface Position Message and that it is the correct value.

Step 3: Surface Position Message – "Ground Track" Subfield (§2.2.3.2.4.3, §2.2.3.2.4.4 and §2.2.5.2.2.c)

Purpose/Introduction:

Any change in Ground Track identified in §2.2.3.2.4.3 and §2.2.3.2.4.4 **shall** be reflected in the appropriate Ground Track subfields of the next scheduled Surface Position Message transmission provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Surface Position Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Surface status. Continue transmitting Surface Position Messages at the nominal rate with all parameters unchanged. Verify that the Ground Track subfields in the Surface Position Message correctly matches the Ground Track subfield values from the Table 2-19 and Table 2-20 (§2.2.3.2.4.3 and §2.2.3.2.4.4).

Change input to the ADS-B System so as to affect the Ground Track subfield values so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Surface Position Message transmission. Verify that the Ground Track subfield values have changed in the next transmitted Surface Position Message and that they contain the correct values.

Step 4: Surface Position Message – "CPR Format" Subfield (§2.2.3.2.4.6 and 2.2.5.2.2.d)

Appropriate test procedures to verify §2.2.5.2.2.d are provided in §2.4.3.2.3.7.2 and §2.4.3.2.3.8.2.

Step 5: Surface Position Message – "Encoded Latitude" Subfield (§2.2.3.2.4.7 and §2.2.5.2.2.e)

Appropriate test procedures to verify §2.2.5.2.2.e are provided in §2.4.3.2.3.7.2 and §2.4.3.2.3.8.2.

Step 6: Surface Position Message – "Encoded Longitude" Subfield (§2.2.3.2.4.8 and §2.2.5.2.2.f)

Appropriate test procedures to verify §2.2.5.2.2.f are provided in §2.4.3.2.3.7.2 and §2.4.3.2.3.8.2.

2.4.5.2.3 Verification of Aircraft Identification and Category Message Latency (§2.2.5.2.3)

Purpose/Introduction:

This test verifies the latency of the Aircraft Identification and Category Message.

Step 1: Aircraft Identification and Category Message – “TYPE” Subfield (§2.2.3.2.5.1 and §2.2.5.2.3.a)

Purpose/Introduction:

The TYPE information for the Aircraft Identification Message should be fixed and therefore not change. However, if changes are imposed, any such change in the TYPE information identified in §2.2.3.2.5.1 **shall** be reflected in the TYPE subfield of the Aircraft Identification Message once the data has been stable (i.e., no changes) for a period of 4 seconds.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Identification Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Continue transmitting Aircraft Identification Messages at the nominal rate with all parameters unchanged.

Change input to the ADS-B System so as to force a change in the TYPE subfield value. Continue transmitting Aircraft Identification Messages at the nominal rate with all parameters unchanged for a minimum of 4 seconds. Verify that the Aircraft Identification Message accurately reflects the change in the TYPE subfield once the data has been unchanged for a period of 4 seconds.

Step 2: Aircraft Identification and Category Message – “Emitter Category” Subfield (§2.2.3.2.5.2 and §2.2.5.2.3.b)

Purpose/Introduction:

ADS-B Emitter Category information for the Aircraft Identification Message should be fixed and therefore not change. However, if changes are imposed, any such change in the ADS-B Emitter Category information identified in §2.2.3.2.5.2 **shall** be reflected in the ADS-B Emitter Category subfield of the Aircraft Identification Message once the data has been stable (i.e., no changes) for a period of 4 seconds.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Identification Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Continue transmitting Aircraft Identification Messages at the nominal rate with all parameters unchanged.

Change input to the ADS-B System so as to force a change in the ADS-B Emitter Category subfield value. Continue transmitting Aircraft Identification Messages at the nominal rate with all parameters unchanged for a minimum of 4 seconds. Verify that the Aircraft Identification Message accurately reflects the change in the ADS-B Emitter Category subfield once the data has been unchanged for a period of 4 seconds.

Step 3: Aircraft Identification and Category Message – "Character" Subfields (§2.2.3.2.5.3 and §2.2.5.2.3.c)

Purpose/Introduction:

Any change in Character information identified in §2.2.3.2.5.3 **shall** be reflected in the appropriate Character subfields of the Aircraft Identification message once the data has been stable (i.e., no changes) for a period of 4 seconds.

Measurement Procedure:

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Identification Messages by providing position information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Continue transmitting Aircraft Identification Messages at the nominal rate with all parameters unchanged.

Change input to the ADS-B System so as to force a change in the Character subfield value. Continue transmitting Aircraft Identification Messages at the nominal rate with all parameters unchanged for a minimum of 4 seconds. Verify that the Aircraft Identification Message accurately reflects the change in the Character subfield once the data has been unchanged for a period of 4 seconds.

2.4.5.2.4 Verification of Airborne Velocity Message – Subtype=1 Latency (§2.2.5.2.4, §2.2.3.2.6.1)

Purpose/Introduction:

The following test procedures are used to test Airborne Velocity Messages – Subtype=1 transmitted by Airborne ADS-B Transmitting Subsystems when Velocity Over Ground information is available, and the transmitting device is installed in an environment having NON-supersonic airspeed capabilities. These test procedures verify that any changes in the data used to structure the subfields of the Airborne Velocity Message - Subtype=1 are reflected in the affected subfield of the next scheduled Airborne Velocity Message - Subtype=1 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message - Subtype=1 transmission.

Measurement Procedure:

Step 1: Airborne Velocity Message - Subtype=1 – "TYPE" Subfield (§2.2.3.2.6.1.1 and §2.2.5.2.4)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=1 by providing subsonic velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non zero subsonic velocity data to the ADS-B System. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Verify that the TYPE subfield in the Airborne Velocity Message –

Subtype=1 equals 19, which is the only TYPE value assigned to Airborne Velocity Messages.

Step 2: Airborne Velocity Message - Subtype=1 – "Subtype" Subfield (§2.2.3.2.6.1.2 and §2.2.5.2.4)

Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Increase the velocity data input to the ADS-B System to a supersonic value so that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Subtype" subfield value has changed to TWO (2) in the next transmitted Airborne Velocity Message.

Step 3: Airborne Velocity Message - Subtype=1 – "Intent Change Flag" Subfield (§2.2.3.2.6.1.3 and §2.2.5.2.4)

Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to cause a change to occur in the Intent Change Flag so that it is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the Intent Change Flag subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

Step 4: Airborne Velocity Message - Subtype=1 – "NAC_V" Subfield (§2.2.3.2.6.1.5 and §2.2.5.2.4)

Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Verify that the NAC_V value equals Zero (0). Insert changed data to the ADS-B System to cause a change to occur in the NAC_V value and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the NAC_V subfield value has changed to the correct value in the next transmitted Airborne Velocity Message.

Step 5: Airborne Velocity Message - Subtype=1 – "East/West Direction Bit" Subfield (§2.2.3.2.6.1.6 and §2.2.5.2.4)

Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Verify that the East/West Direction Bit equals Zero (0). Insert changed data to the ADS-B System to cause a change to occur in the East/West Direction Bit so that the direction will become "West" and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the East/West Direction Bit subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

Step 6: Airborne Velocity Message - Subtype=1 – "East/West Velocity" Subfield (§2.2.3.2.6.1.7 and §2.2.5.2.4)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=1 by providing subsonic velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non zero subsonic East/West Velocity data to the ADS-B System. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged.

Insert changed data to the ADS-B System to cause a change to occur in the East/West Velocity so that it is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the East/West Velocity subfield value has changed in the next transmitted Airborne Velocity Message and that the value in the subfield is correct.

Step 7: Airborne Velocity Message - Subtype=1 – "North/South Direction Bit" Subfield (§2.2.3.2.6.1.8 and §2.2.5.2.4)

Repeat the tests in Step 6 above changing the word "East" to "North" and the word "West" to "South."

Step 8: Airborne Velocity Message - Subtype=1 – "North/South Velocity" Subfield (§2.2.3.2.6.1.9 and §2.2.5.2.4)

Repeat the tests in Step 7 above changing the words "East/West" to "North/South."

Step 9: Airborne Velocity Message - Subtype=1 – "Vertical Rate Source Bit" Subfield (§2.2.3.2.6.1.10 and §2.2.5.2.4)

a. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Verify that the Source Bit for Vertical Rate equals Zero (0), indicating receipt of Vertical Rate information from a Geometric Source. Insert changed data to the ADS-B System to cause a change to occur in the Source Bit for Vertical Rate so that the Vertical Rate information will come from a Barometric Source, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Source Bit for Vertical Rate" subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

b. Continue transmitting Airborne Velocity Messages – Subtype=1 at the nominal rate with all parameters unchanged and verify that the Source Bit for Vertical Rate contains the value ONE (1). Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to cause a change to occur in the Source Bit for Vertical Rate so that the Vertical rate information will come from a Geometric Source, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Source Bit for Vertical Rate" subfield value has changed to ZERO (0) in the next transmitted Airborne Velocity Message.

Step 10: Airborne Velocity Message - Subtype=1 – "Sign Bit for Vertical Rate" Subfield (§2.2.3.2.6.1.11 and §2.2.5.2.4)

a. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Verify that the "Sign Bit for Vertical Rate" subfield equals ZERO (0), indicating Vertical Rate information in the UP Direction. Insert changed data to the ADS-B System to cause a change to occur in the "Sign Bit for Vertical Rate" so that the Vertical Direction information will be DOWN, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Sign Bit for Vertical Rate" subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

b. Continue transmitting Airborne Velocity Messages – Subtype=1 at the nominal rate with all parameters unchanged and verify that the "Sign Bit for Vertical Rate" subfield contains the value of ONE (1). Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to cause a change to occur in the "Sign Bit for Vertical Rate" so that the Vertical Direction information will be UP, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Sign Bit for Vertical Rate" subfield value has changed to ZERO (0) in the next transmitted Airborne Velocity Message.

Step 11: Airborne Velocity Message - Subtype=1 – "Vertical Rate" Subfield (§2.2.3.2.6.1.12 and §2.2.5.2.4)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=1 by providing subsonic velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid non zero Vertical Rate data to the ADS-B System. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged.

Insert changed data to the ADS-B System to cause a change to occur in the Vertical Rate so that it is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the Vertical Rate subfield value has changed in the next transmitted Airborne Velocity Message and that the value in the subfield is correct.

Step 12: Airborne Velocity Message - Subtype=1 – "Difference From Barometric Altitude Sign Bit" Subfield (§2.2.3.2.6.1.14 and §2.2.5.2.4)

a. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Verify that the Geometric Altitude Source data is greater than (above) the Barometric. Verify that the Difference From Barometric Altitude Sign Bit equals Zero (0). Insert changed data to the ADS-B System to cause a change to occur in the Difference From Barometric Altitude Sign Bit so that the Geometric Altitude Source Data is less than (below) Barometric, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the Difference From Barometric Altitude Sign Bit subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

b. Continue transmitting Airborne Velocity Messages – Subtype=1 at the nominal rate with all parameters unchanged and verify that the Difference From Barometric Altitude Sign Bit contains the value ONE (1). Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to cause a change to occur in the Difference From Barometric Altitude Sign Bit so that the Geometric Altitude Source data is greater than (above) the Barometric, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the Difference From Barometric Altitude Sign Bit subfield value has changed to ZERO (0) in the next transmitted Airborne Velocity Message.

Step 13: Airborne Velocity Message - Subtype=1 – "Difference From Barometric Altitude" Subfield (§2.2.3.2.6.1.15 and §2.2.5.2.4)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=1 by providing subsonic velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid Geometric Altitude Source data and Barometric Altitude data. Continue transmitting Airborne Velocity Messages - Subtype=1 at the nominal rate with all parameters unchanged.

Insert changed data to the ADS-B System to cause a change to occur in the "Difference From Barometric Altitude" subfield so that it is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Difference From Barometric Altitude" subfield value has changed in the next transmitted Airborne Velocity Message and that the value in the subfield is correct.

2.4.5.2.5 Verification of Airborne Velocity Message – Subtype=2 Latency (§2.2.3.2.6.2, §2.2.5.2.5)

Purpose/Introduction:

The following test procedures are used to test Airborne Velocity Messages – Subtype=2 transmitted by Airborne ADS-B Transmitting Subsystems when Velocity Over Ground information is available, and the transmitting device is installed in an environment having Supersonic airspeed capabilities.

Measurement Procedure:

Repeat all tests in §2.4.5.2.4 Steps 1 through 15 changing all occurrences of 'Subtype=1' to 'Subtype=2' and all occurrences of "subsonic" to "supersonic" and vice versa.

2.4.5.2.6 Verification of Airborne Velocity Message – Subtype=3 Latency (§2.2.3.2.6.3, §2.2.5.2.6)

Purpose/Introduction:

The following test procedures are used to test Airborne Velocity Messages – Subtype=3 transmitted by Airborne ADS-B Transmitting Subsystems when Velocity Over Ground information is NOT available, and the transmitting device is installed in an environment having NON-supersonic airspeed capabilities. These test procedures verify that any changes in the data used to structure the subfields of the Airborne Velocity Message - Subtype=3 are reflected in the affected subfield of the next scheduled Airborne Velocity Message - Subtype=3 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message - Subtype=1 transmission.

Measurement Procedure:

Step 1: Airborne Velocity Message - Subtype=3 – "TYPE" Subfield (§2.2.3.2.6.3.1 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 1 for the TYPE subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 2: Airborne Velocity Message - Subtype=3 – "Subtype" Subfield (§2.2.3.2.6.3.2 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 2 for the Subtype subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 3: Airborne Velocity Message - Subtype=3 – "Intent Change Flag" Subfield (§2.2.3.2.6.3.3 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 3 for the "Intent Change Flag" subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 4: Airborne Velocity Message - Subtype=3 – "NAC_V" Subfield (§2.2.3.2.6.3.5 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 5 for the NAC_V subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 5: Airborne Velocity Message - Subtype=3 – "Heading Status" Subfield (§2.2.3.2.6.3.6 and §2.2.5.2.6)

a. Continue transmitting Airborne Velocity Messages - Subtype=3 at the nominal rate with all parameters unchanged. Verify that the Heading Status

Bit equals ZERO (0), indicating that Heading Data is available. Insert changed data to the ADS-B System to indicate that Heading Data is NOT available, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the Heading Status Bit subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

b. Continue transmitting Airborne Velocity Messages – Subtype=3 at the nominal rate with all parameters unchanged and verify that the Heading Status Bit contains the value ONE (1). Continue transmitting Airborne Velocity Messages - Subtype=3 at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to indicate that Heading Data IS available, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the Heading Status Bit subfield value has changed to ZERO (0) in the next transmitted Airborne Velocity Message.

Step 6: Airborne Velocity Message - Subtype=3 – "Heading" Subfield (§2.2.3.2.6.3.7 and §2.2.5.2.6)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=3 by providing subsonic velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid "Heading" data. Continue transmitting Airborne Velocity Messages - Subtype=3 at the nominal rate with all parameters unchanged.

Insert changed data to the ADS-B System to cause a change to occur in the "Heading" so that it is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Heading" subfield value has changed in the next transmitted Airborne Velocity Message and that the value in the subfield is correct.

Step 7: Airborne Velocity - Subtype=3 – "Airspeed Type" Subfield (§2.2.3.2.6.3.8 and §2.2.5.2.6)

a. Continue transmitting Airborne Velocity Messages - Subtype=3 at the nominal rate with all parameters unchanged. Verify that the "Airspeed Type" subfield equals ZERO (0), indicating that the Airspeed Type is "Indicated Airspeed" (IAS). Insert changed data to the ADS-B System to indicate that Airspeed Type has changed to True Airspeed (TAS), and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Airspeed Type" subfield value has changed to ONE (1) in the next transmitted Airborne Velocity Message.

b. Continue transmitting Airborne Velocity Messages – Subtype=3 at the nominal rate with all parameters unchanged and verify that the "Airspeed Type" subfield contains the value ONE (1). Continue transmitting Airborne Velocity Messages - Subtype=3 at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to indicate that the

"Airspeed Type" has changed to Indicated Airspeed, and so that the change is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Airspeed Type" subfield value has changed to ZERO (0) in the next transmitted Airborne Velocity Message.

Step 8: Airborne Velocity Message - Subtype=3 – "Airspeed" Subfield (§2.2.3.2.6.3.9 and §2.2.5.2.6)

Configure the ADS-B Transmitting Subsystem to transmit Airborne Velocity Messages – Subtype=3 by providing subsonic velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Provide valid "Airspeed" data. Continue transmitting Airborne Velocity Messages - Subtype=3 at the nominal rate with all parameters unchanged.

Insert changed data to the ADS-B System to cause a change to occur in the "Airspeed" subfield so that it is detected at least 100 milliseconds prior to the next scheduled Airborne Velocity Message transmission. Verify that the "Airspeed" subfield value has changed in the next transmitted Airborne Velocity Message and that the value in the subfield is correct.

Step 9: Airborne Velocity Message - Subtype=3 – "Vertical Rate Source" Subfield (§2.2.3.2.6.3.10 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 10 for the Source Bit For Vertical Rate subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 10: Airborne Velocity Message - Subtype=3 – "Sign Bit for Vertical Rate" Subfield (§2.2.3.2.6.3.11 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 11 for the "Sign Bit for Vertical Rate" subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 11: Airborne Velocity Message - Subtype=3 – "Vertical Rate" Subfield (§2.2.3.2.6.3.12 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 12 for the "Vertical Rate" subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 12: Airborne Velocity Message - Subtype=3 – "Difference From Barometric Altitude Sign Bit" Subfield (§2.2.3.2.6.1.14 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 14 for the Difference From Barometric Altitude Sign Bit subfield changing all occurrences of Subtype=1 to Subtype "3."

Step 13: Airborne Velocity Message - Subtype=3 – "Difference From Barometric Altitude" Subfield (§2.2.3.2.6.3.15 and §2.2.5.2.6)

Repeat the test outlined in §2.4.5.2.4, Step 15 for the Difference From Barometric Altitude subfield changing all occurrences of Subtype=1 to Subtype "3."

2.4.5.2.7 Verification of Airborne Velocity Message – Subtype=4 Latency (§2.2.3.2.6.4, §2.2.5.2.7)

Purpose/Introduction:

The following test procedures are used to test Airborne Velocity Messages – Subtype=4 transmitted by Airborne ADS-B Transmitting Subsystems when Velocity Over Ground information is NOT available, and the transmitting device is installed in an environment having supersonic airspeed capabilities.

Measurement Procedure:

Repeat all tests in §2.4.5.2.6 Steps 1 through 15 changing all occurrences of 'Subtype=3' to 'Subtype=4' and all occurrences of "subsonic" to "supersonic" and vice versa.

2.4.5.2.8 Verification of Airborne Velocity Message – Subtype "5" Latency (§2.2.5.2.8)

RESERVED FOR FUTURE APPLICATION

No specific test procedure is required to validate §2.2.5.2.8.

2.4.5.2.9 Verification of Airborne Velocity Message – Subtype "6" Latency (§2.2.5.2.9)

RESERVED FOR FUTURE APPLICATION

No specific test procedure is required to validate §2.2.5.2.9.

2.4.5.2.10 Verification of Airborne Velocity Message – Subtype "7" Latency (§2.2.5.2.10)

RESERVED FOR FUTURE APPLICATION

No specific test procedure is required to validate §2.2.5.2.10.

2.4.5.2.11 Verification of Target State and Status Message Latency (§2.2.3.2.7.1, §2.2.5.2.11)

Purpose/Introduction:

The following test procedures verify that any changes in the data used to structure the subfields of the Target State and Status Message are reflected in the affected subfield of the next scheduled Target State and Status Message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Target State and Status Message transmission.

Measurement Procedure:

Step 1: Target State and Status – "TYPE" Subfield (§2.2.3.2.7.1.1 and §2.2.5.2.11)

Configure the ADS-B Transmitting Subsystem to transmit Target State and Status Messages by providing valid trajectory information at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status. Verify that the TYPE subfield in the Target State and Status Message equals 29, which is the only TYPE value assigned to Target State and Status Messages.

Step 2: Target State and Status – "Subtype" Subfield (§2.2.3.2.7.1.2)

Continue transmitting Target State and Status Messages at the nominal rate with all parameters unchanged. Verify that the Subtype subfield in the Target State and Status Messages equals ZERO (0), which is the only Subtype value currently assigned to Target State and Status Messages.

Step 3: Target State and Status – "Selected Altitude Type" Subfield (§2.2.3.2.7.1.3.2)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 4: Target State and Status – "MCP/FCU Selected Altitude or FMS Selected Altitude" Subfield (§2.2.3.2.7.1.3.3)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 5: Target State and Status – "Barometric Pressure Setting (Minus 800 millibars)" Subfield (§2.2.3.2.7.1.3.4)

Continue transmitting Target State and Status Messages at the nominal rate with ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 6: Target State and Status – "Selected Heading Status" Subfield (§2.2.3.2.7.1.3.5)

Continue transmitting Target State and Status Messages at the nominal rate with ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 7: Target State and Status – "Selected Heading Sign" Subfield (§2.2.3.2.7.1.3.6)

Continue transmitting Target State and Status Messages at the nominal rate with ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 8: Target State and Status – "Selected Heading" Subfield (§2.2.3.2.7.1.3.7)

Continue transmitting Target State and Status Messages at the nominal rate with ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 9: Target State and Status – "NAC_P" Subfield (§2.2.3.2.7.1.3.8)

Continue transmitting Target State and Status Messages at the nominal rate with a NAC_P value of Zero indicated. Verify that the NAC_P Subfield is set to ALL ZEROs (binary 0000). For each NAC_P in the binary column of Table 2-71 insert changed data to the ADS-B System to cause a change to occur in the NAC_P subfield, and so that the change is detected at least 100 milliseconds prior to the next scheduled Target State and Status Message transmission. Verify that the binary value in the NAC_P Subfield equals the corresponding binary value in the same row of the table.

Step 10: Target State and Status – "NIC_{BARO}" Subfield (§2.2.3.2.7.1.3.9)

Continue transmitting Target State and Status Messages at the nominal rate with a non-cross checked Gilham altitude indicated. Verify that the NIC_{BARO} Subfield equals ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the NIC_{BARO} subfield with a cross checked Gilham altitude indicated and such that the change is detected at least 100 milliseconds prior to the next scheduled Target State and Status Message transmission. Verify that the NIC_{BARO} Subfield equals ONE (1).

Step 11: Target State and Status – "SIL" and "SIL Supplement" Subfields (§2.2.3.2.7.1.3.1, §2.2.3.2.7.1.3.10)

Continue transmitting Target State and Status Messages at the nominal rate with Unknown SIL Data. Verify that the SIL subfield equals ZERO (binary 00). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield to indicate 1×10^{-3} per flight hour, and so that the change is detected at least 100 milliseconds prior to the next scheduled Target State and Status Message transmission. Verify that the SIL subfield equals ONE (binary 01) and that the SIL Supplement subfield equals ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield to indicate 1×10^{-5} per sample, and so that the change is detected at least 100 milliseconds prior to the next scheduled Target State and Status Message transmission. Verify that the SIL subfield equals TWO (binary 10) and that the SIL Supplement subfield equals ONE (1). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield 1×10^{-7} per flight hour, and so that the change is detected at least 100 milliseconds prior to the next scheduled Target State and Status Message transmission. Verify that the SIL subfield equals THREE (binary 11) and that the SIL Supplement equals ZERO (0).

Step 12: Target State and Status – "Status of MCP/FCU Mode Bits" (§2.2.3.2.7.1.3.11)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 13: Target State and Status – "Autopilot Engaged" Subfield (§2.2.3.2.7.1.3.12)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 14: Target State and Status – "VNAV Mode Engaged" Subfield (§2.2.3.2.7.1.3.13)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 15: Target State and Status – "Altitude Hold Mode" Subfield (§2.2.3.2.7.1.3.14)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 16: Target State and Status – "Approach Mode" Subfield (§2.2.3.2.7.1.3.16)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

Step 17: Target State and Status – "TCAS Operational" Subfield (§2.2.3.2.7.1.3.17)

Continue transmitting Target State and Status Messages at the nominal rate ZZZZZZZZZZZ NEED TEST PROCEDURE HERE ZZZZZZZZZZZZZZ

2.4.5.2.12 Verification of Aircraft Operational Status Message Latency (§2.2.3.2.7.2, §2.2.5.2.12)

Purpose/Introduction:

These test procedures verify that any changes in the data used to structure the subfields of the Aircraft Operational Status Message are reflected in the affected subfield of the next scheduled Aircraft Operational Status Message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission.

Measurement Procedure:

Step 1: Aircraft Operational Status Message - "TYPE" Subfield (§2.2.3.2.7.2.1 and §2.2.5.2.12)

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing data at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with all parameters unchanged. Verify that the TYPE subfield in the Aircraft Operational Status Message equals 31, which is the only TYPE value assigned to Aircraft Operational Status Messages.

Step 2: Aircraft Operational Status Message - "Subtype" Subfield (§2.2.3.2.7.2.2 and §2.2.5.2.12)

Continue transmitting Aircraft Operational Status Messages at the nominal rate with all parameters unchanged. Verify that the Subtype subfield in the Aircraft Operational Status Messages equals ZERO (0).

Step 3: Aircraft Operational Status Message - "Capability Class" (CC) Subfield (§2.2.3.2.7.2.3 and §2.2.5.2.12)

a. Capability Class Code for "TCAS Operational" (§2.2.3.2.7.2.3.2)

Continue transmitting Aircraft Operational Status Messages at the nominal rate with TCAS Operational indicated. Verify that ME bit 11 is set to ONE (1). Insert changed data to the ADS-B System to cause a change to occur in the Capability Class subfield with TCAS not operational indicated, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 11 is set to ZERO (0).

b. Capability Class Code for "1090ES IN" (§2.2.3.2.7.2.3.3)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with 1090ES Receive capability indicated. Verify that ME bit 12 is set to ONE (1). Insert changed data to the ADS-B System to cause a change to occur in the Capability Class subfield which indicates that there is no 1090ES Receiver available, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 12 is set to ZERO (0).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Rerun this procedure and verify that the Subtype is set to ONE (1) and that ME bit 12 is set to the appropriate state.

c. Capability Class Code for "ARV Report Capability" (§2.2.3.2.7.2.3.4)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with no capability for (ARV) Reports indicated. Verify that ME bit 15 is set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the Capability Class subfield with Capability for sending messages to support (ARV) Reports indicated, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 15 is set to ONE (1).

d. Capability Class Code for "TS Report Capability" (§2.2.3.2.7.2.3.5)

Continue transmitting Aircraft Operational Status Messages at the nominal rate with no capability for (TS) reports indicated. Verify that ME bit 16 is set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the Capability Class subfield with Capability for sending messages to support (TS) reports indicated, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 16 is set to ONE (1).

e. Capability Class Code for "TC Report Capability" (§2.2.3.2.7.2.3.6)

Continue transmitting Aircraft Operational Status Messages at the nominal rate with no capability for (TC) reports indicated. Verify that the TC Report Capability subfield equals ZERO (binary 00). Insert changed data to the ADS-B System to cause a change to occur in the TC Report Capability subfield to indicate the capability of sending messages to support TC+0 Reports only, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the TC Report Capability subfield equals ONE (binary 01). Insert changed data to the ADS-B System to cause a change to occur in the TC Report Capability subfield to indicate the capability of sending information for multiple TC Reports, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the TC Report Capability subfield equals TWO (binary 10).

f. Capability Class Code for "Position Offset Applied (POA)" (§2.2.3.2.7.2.3.7)

Set the ADS-B Transmitting Subsystem to On-Ground Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with no Position Offset Applied indicated. Verify that ME bit 11 is set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the (POA) subfield with Position Offset Applied indicated, and such that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 11 is set to ONE (1).

g. Capability Class Code for "UAT IN" (§2.2.3.2.7.2.3.10)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with UAT Receive capability indicated. Verify that ME bit 19 is set to ONE (1). Insert changed data to the ADS-B System to cause a change to occur in the Capability Class subfield which indicates that there is no UAT Receiver available, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 19 is set to ZERO (0).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Rerun this procedure and verify that the Subtype is set to ONE (1) and that ME bit 16 is set to the appropriate state.

Step 4: Aircraft Operational Status Message – Subtype 0/1 - "Operational Mode" (OM) Subfield (§2.2.3.2.7.2.4 and §2.2.5.2.12)

a. Operational Mode Code for "TCAS/ACAS Resolution Advisory Active" (§2.2.3.2.7.2.4.2)

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing data at the nominal update rate.

Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with no TCAS/ACAS Resolution Advisory Active indicated. Verify that ME bits 25,26 and 27 are all set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the Operational Mode subfield with a TCAS/ACAS Resolution Advisory Active indicated. Verify that ME bits 25 and 26 are both set to ZERO (0) and that ME bit 27 is set to ONE (1).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and verify the same binary values and verify that the Subtype is set to ONE (1).

b. Operational Mode Code for "IDENT Switch Active" (§2.2.3.2.7.2.4.3)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with IDENT switch not active indicated. Verify that ME bit 28 is set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the Operational Mode subfield with IDENT switch active indicated. Verify that ME bit 28 is set to ONE (1).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and verify the same binary values and verify that the Subtype is set to ONE (1).

c. Operational Mode Code for "Reserved for Receiving ATC Services" (§2.2.3.2.7.2.4.4)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate. Verify that ME bit 29 is set to ZERO (0).

d. Operational Mode Code for "Single Antenna Flag" (§2.2.3.2.7.2.4.5)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate. Provide stimulus to indicate that the aircraft has a single antenna. Verify that ME bit 30 is set to ONE (1). Insert changed data to the ADS-B System to indicate that the aircraft has multiple antenna, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 30 is set to ZERO (0). Reset the ADS-B Transmitting Subsystem to On-Ground Status and rerun the above tests and verify that ME bit is set appropriately.

e. Operational Mode Code for "System Design Assurance" (§2.2.3.2.7.2.4.6)

Continue transmitting Aircraft Operational Status Messages at the nominal rate with Unknown SIL Data, and unknown SDA data. Verify that the SIL subfield (ME bits 51-52) equals ZERO (binary 00) and that the SDA subfield (ME bits 31-32) equals ZERO (binary 00). Insert changed data to the ADS-B

System to cause a change to occur in the SIL subfield to indicate 1 x 10^{-3} per flight hour, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the SIL subfield equals ONE (binary 01), and that the SIL Supplement subfield (ME bit 55) equals ZERO (0), and that the SDA subfield equals ONE (1). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield to indicate 1 x 10^{-5} per sample, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the SIL and SDA subfields equal TWO (binary 10) and that the SIL Supplement subfield equals ONE (1). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield 1 x 10^{-7} per flight hour, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the SIL and SDA subfields equal THREE (binary 11) and that the SIL Supplement equals ZERO (0).

f. Operational Mode Code for "GPS Antenna Offset" (§2.2.3.2.7.2.4.7)

Set the ADS-B Transmitting Subsystem to On-Ground Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with no Position Offset Applied indicated. Verify that ME bit 11 is set to ZERO (0). ZZZZZZZZZ NEED MORE TEST PROCEDURE HERE ZZZZZZZZZZZ

Step 5: Aircraft Operational Status Message – "Aircraft Length and Width Code" Subfield (§2.2.3.2.7.2.11)

Set the ADS-B Transmitting Subsystem to On-Ground Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with the Minimum Length and Width values from Table 2-74 indicated. Verify that the ME bits 21 through 24 are set to ALL ZEROs (binary 0000). For each Length and Width combination in Table 2-74 insert changed data to the ADS-B System to cause a change to occur in the Length and Width subfield, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the binary values in ME bits 21 through 24 equals the corresponding binary values in the same row of the table.

Step 6: Aircraft Operational Status Message – Subtype "0/1" – "Version Number" Subfield

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing data at the nominal update rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with all parameters unchanged. Verify that ME bits 41 through 43 are set to ONE (binary 001).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and verify the same binary values and verify that the Subtype is set to ONE (1).

Step 7: Aircraft Operational Status Message – Subtype "0/1" – "NIC Supplement" Subfield (§2.2.3.2.7.2.6)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with a TYPE Code equal to ZERO indicated. Verify that the NIC Supplement Subfield is set to ZERO (0). For each Airborne Position TYPE Code listed in Table 2-70 insert changed data to the ADS-B System to cause a change to occur in the Airborne Position TYPE Code subfield, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the binary value in the NIC Supplement Subfield equals the corresponding binary value in the Airborne NIC Supplement column in the same row of Table 2-70.

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and for each Surface Position TYPE Code listed in Table 2-70 insert changed data to the ADS-B System to cause a change to occur in the Surface Position TYPE Code subfield, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the binary value in the NIC Supplement Subfield equals the corresponding binary value in the Surface NIC Supplement column in the same row of Table 2-70.

Step 8: Aircraft Operational Status Message – Subtype "0/1" – "NAC_P" Subfield (§2.2.3.2.7.2.7)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with an EPU greater than or equal to 10 NM indicated. Verify that the NAC_P Subfield is set to ZERO (binary 0000). For each EPU range listed in Table 2-71 insert changed data to the ADS-B System to cause a change to occur in the NAC_P subfield, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the binary value in the NAC_P Subfield equals the corresponding binary value in the NAC_P Binary column in the same row of the table.

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and verify the same binary values and verify that the Subtype is set to ONE (1).

Step 9: Aircraft Operational Status Message – Subtype "0/1" – "SIL" Subfield (§2.2.3.2.7.2.9)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with Unknown SIL Data. Verify that the SIL subfield equals ZERO (binary 00). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield to indicate 1 x 10^{-3} per flight hour or per operation, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the SIL subfield equals ONE (binary 01). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield to indicate 1 x 10^{-5} per flight hour or per operation, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the SIL subfield equals TWO (binary 10). Insert changed data to the ADS-B System to cause a change to occur in the SIL subfield 1 x 10^{-7} per flight hour or per operation, and so that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the SIL subfield equals THREE (binary 11).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and verify the same binary values and verify that the Subtype is set to ONE (1).

Step 10: Aircraft Operational Status Message – Subtype “0” – “NIC_{BARO}” Subfield (§2.2.3.2.7.2.10)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status Messages at the nominal rate with a non-cross checked Gilham altitude indicated. Verify that the NIC_{BARO} Subfield equals ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the NIC_{BARO} subfield with a cross checked Gilham altitude indicated and such that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that the NIC_{BARO} Subfield equals ONE (1).

Step 11: Aircraft Operational Status Message – Subtype=1 – “Track Angle/Heading” Subfield (§2.2.3.2.7.2.12)

Set the ADS-B Transmitting Subsystem to On-Ground Status. Continue transmitting Aircraft Operational Status – Subtype=1 Messages at the nominal rate with Track Angle indicated. Verify that ME bit 53 is set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the Track Angle/Heading subfield with Heading indicated and such that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 53 is set to ONE (1).

Step 12: Aircraft Operational Status Message – Subtype “0/1” – “HRD” Subfield (§2.2.3.2.7.2.13)

Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Aircraft Operational Status – Subtype “0” Messages at the nominal rate with True North indicated. Verify that ME bit 54 is set to ZERO (0). Insert changed data to the ADS-B System to cause a change to occur in the HRD subfield with Magnetic North indicated, such that the change is detected at least 100 milliseconds prior to the next scheduled Aircraft Operational Status Message transmission. Verify that ME bit 54 is set to ONE (1).

Set the ADS-B Transmitting Subsystem to On-Ground Status. Repeat this procedure and verify the same binary values and verify that the Subtype is set to ONE (1).

2.4.5.2.13 Verification of TYPE 23 Test Message Latency (§2.2.5.2.13)

Purpose/Introduction:

The ADS-B Transmission Device Message Processor processes Vendor Specified data for ADS-B Test Messages specified in §2.2.3.2.7.3 with any change in data being reflected in the next scheduled Test Message provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Test Message transmission.

Measurement Procedure:

Step 1: Test Message – "TYPE" Subfield (§2.2.3.2.7.3)

Configure the ADS-B Transmitting Subsystem to transmit Test Messages by providing valid information at the nominal update rate. Provide the data externally at the interface to the ADS-B System. Set the ADS-B Transmitting Subsystem to Airborne status. Verify that the TYPE subfield in the Test Message equals 23, which is the only TYPE value assigned to Test Messages.

Step 2: Test Message (§2.2.3.2.7.3)

Continue transmitting Test Messages at the nominal rate with all parameters unchanged. Insert changed data to the ADS-B System to cause a change to occur in the Test Message so that it is detected at least 100 milliseconds prior to the next scheduled Test Message transmission. Verify that the Test subfield value has changed as expected in the next transmitted Test Message.

2.4.5.2.14 Verification of TYPE 24 Message Latency (§2.2.5.2.14)

RESERVED FOR FUTURE APPLICATION

No specific test procedure is required to validate §2.2.5.2.14.

2.4.5.2.15 Verification of TYPE 25 Message Latency (§2.2.5.2.15)

RESERVED FOR FUTURE APPLICATION

No specific test procedure is required to validate §2.2.5.2.15.

2.4.5.2.16 Verification of TYPE 26 Message Latency (§2.2.5.2.16)

RESERVED FOR FUTURE APPLICATION

No specific test procedure is required to validate §2.2.5.2.16.

2.4.5.2.17 Verification of TYPE 27 Message Latency (§2.2.5.2.17)

RESERVED for future use of Trajectory Change

No specific test procedure is required to validate §2.2.5.2.17.

2.4.5.2.18 Verification of Aircraft Status Messages – Subtype=1 (§2.2.5.2.18)

Purpose/Introduction:

Any change in the data used to structure the subfields of the Aircraft Status Message – Subtype=1 (Emergency/Priority Status) are reflected in the affected subfield of the next scheduled Aircraft Status Message – Subtype=1 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Aircraft Status Message – Subtype=1 transmission as specified in §2.2.5.2.18.

Measurement Procedure:

Step 1: Aircraft Status Message – Subtype=1 – TYPE Subfield

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing data at the nominal rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged, ensuring that there is "No Emergency" indicated. Verify that the Aircraft Status Message is not being broadcast. Insert changed data into the ADS-B System indicating an emergency condition specified in Table 2-57. Verify that the TYPE subfield, in the transmitted Aircraft Status Message with Subtype=1, equals 28.

Step 2: Aircraft Status Message – Subtype=1 – SUBTYPE Subfield

Continue transmitting Aircraft Status Messages with Subtype=1 at the nominal rate with all parameters unchanged. Verify that the SUBTYPE subfield in the Aircraft Status Message equals ONE (1).

Step 3: Aircraft Status Message – Subtype=1 – Emergency/Priority Status

Continue transmitting Aircraft Status Messages with Subtype=1 at the nominal rate. Verify that the system generates ADS-B Aircraft Status Messages with Subtype=1 with the "Emergency/Priority Status" subfield set equal to the corresponding binary coding value that was provided as input.

Change the "Emergency/Priority Status" subfield input to the ADS-B System so as to change the emergency being reported, and verify that the change occurs, and that it is detected at least 100 milliseconds prior to the next scheduled Aircraft Status Message with Subtype=1 transmission. Verify that the "Emergency/Priority Status" subfield value has changed in the next transmitted Aircraft Status Message and that it is the correctly reported value.

2.4.5.2.19 Verification of TCAS RA Broadcast Messages – Subtype=2 (§2.2.5.2.19)

Purpose/Introduction:

Any change in the data used to structure the subfields of the Aircraft Status Message – Subtype=2 (TCAS RA Broadcast) are reflected in the affected subfields of the next scheduled Aircraft Status Message – Subtype=2 provided that the change occurs and is detected at least 100 milliseconds prior to the next scheduled Aircraft Status Message – Subtype=2 transmission as specified in §2.2.5.2.19.

Measurement Procedure:

Step 1: Aircraft Status Message – Subtype=2 – TYPE Subfield

Configure the ADS-B Transmitting Subsystem to transmit Airborne Position Messages by providing data at the nominal rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne Status. Continue transmitting Airborne Position Messages at the nominal rate with all parameters unchanged, ensuring that there is no "TCAS RA" indicated. Verify that the Aircraft Status Message is not being broadcast. Insert changed data into the ADS-B System to reflect a TCAS RA condition. Verify that the ADS-B System begins to transmit an Aircraft Status Message with Subtype=2 within 0.5 seconds after the transponder notification of the initiation of the TCAS RA. Verify that the TYPE subfield, in the transmitted Aircraft Status Message with Subtype=2, equals 28.

Step 2: Aircraft Status Message – Subtype=2 – SUBTYPE Subfield

Continue transmitting Aircraft Status Messages with Subtype=2 at the nominal rate with all parameters unchanged. Verify that the SUBTYPE subfield in the Aircraft Status Message equals TWO (2).

Step 3: Aircraft Status Message – Subtype=2 – TCAS RA Data

Continue transmitting Aircraft Status Messages with Subtype=2 at the nominal rate. Verify that the system generates ADS-B Aircraft Status Messages with Subtype=2 with the appropriate subfields set equal to the corresponding binary coding values that are specified from the transponder according to ICAO Annex 10, Volume IV, §4.3.8.4.2.2.

Set the RA Termination flag in the transponder to ONE (1), and verify that the ADS-B System continues to transmit Aircraft Status Messages with Subtype=2 for not less than 10 seconds. Verify that 10 seconds after the RA Termination flag transitions from ZERO (0) to ONE (1) that the ADS-B System terminates broadcast of the Aircraft Status Messages with Subtype "2."

2.4.5.3 Verification of ADS-B Transmission Device Source Slecteion (§2.2.5.3)

Purpose/Introduction:

XXXXXXXXXXXXXXXXXX

2.4.6 Verification of ADS-B Receiving Device Message Processor Characteristics (§2.2.6)

No specific test procedure is required to validate §2.2.6.

2.4.6.1 Verification of ADS-B Message Reception Function Requirements (§2.2.6.1)

The procedures provided in §2.4.6.1.2 **shall** be used to validate performance of §2.4.6.1.

2.4.6.1.1 Verification of ADS-B Message Reception Function Output Message Structure Requirements (§2.2.6.1.1)

The procedures provided in §2.4.6.1.2 **shall** be used to validate performance of §2.4.6.1.1.

2.4.6.1.2 Verification of ADS-B and TIS-B Message Reception Function Output Message Delivery Requirements (§2.2.6.1.2)

Purpose/Introduction:

Figure 2-18 illustrates the transmitted message receipt capabilities and the ***OUTPUT MESSAGE*** delivery requirements. The ADS-B and TIS-B Message Reception Function delivers All *OUTPUT MESSAGES* to the user interface or the Report Assembly function within 2.0 milliseconds of the receipt of the last message bit of the transmitted message.

These test procedures verify that the ADS-B and TIS-B Receiver Function properly receives and decodes all valid ADS-B and TIS-B transmitted messages and delivers the messages to the user interface or to the Report Assembly function.

Measurement Procedure:

Step 1: ADS-B and TIS-B Message ONLY Reception (§2.2.6.1, §2.2.6.1.1, §2.2.17.2)

Provide the ADS-B Receiver under test with MODE-S messages having random data but appropriate "AA" or "PI" fields for the downlink formats DF=0, DF=4, DF=5, DF=11, DF=16, DF=17, DF=18, DF=20, DF=21 and DF=24.

Verify that the ADS-B Receiver DOES NOT generate Output Messages for all of the downlink formats received with the exception of DF=17 and DF=18.

Verify that the ADS-B Receiver delivers appropriate Output Messages to the user interface or to the Report Assembly function for each DF=17 and DF=18 message received and that the Output Message formats are consistent with the requirements of §2.2.6.1.1 (for ADS-B) and §2.2.17.2 (for TIS-B).

Step 2: ADS-B and TIS-B Message Reception (§2.2.6.1, §2.2.6.1.1, §2.2.17.2)

Provide the ADS-B and TIS-B Receiver under test with the ADS-B and TIS-B Messages listed in Table 2-169 in the following manner:

a. The messages **shall** be provided sequentially as listed in Table 2-169 in a burst of 17 messages, beginning with eleven ADS-B Messages and then three TIS-B Messages, followed by three more ADS-B Messages, where:

b. The first preamble pulse of each message is separated from the end of the previous message by 8.0 microseconds, and

c. The burst **shall** be repeated at least four times with the beginning of each burst being separated from the end of the last burst by not more than 2.0 milliseconds.

Table 2-169: ADS-B Message Reception

ADS-B MESSAGE RECEPTION					
BIT #	1 ---- 5	6 - 8	9 --------- 32	33 ------------------------------ 88	89 ------------------ 112
CASE No.	**DF [5]**	**CA (CF) [3]**	**AA [24] (HEX)**	**ME [56] (HEX)**	**PI [24] (HEX)**
1	1 0001	000	AA AA AA	AA AA AA AA AA AA AA	**See Note**
2	1 0001	001	55 55 55	55 55 55 55 55 55 55	
3	1 0001	010	77 77 77	77 77 77 77 77 77 77	
4	1 0001	011	BB BB BB	BB BB BB BB BB BB BB	
5	1 0001	100	DD DD DD	DD DD DD DD DD DD DD	
6	1 0001	101	EE EE EE	EE EE EE EE EE EE EE	
7	1 0001	110	AA AA AA	AA AA AA AA AA AA AA	
8	1 0001	111	55 55 55	55 55 55 55 55 55 55	
9	1 0010	000	AA AA AA	AA AA AA AA AA AA AA	
10	1 0010	000	55 55 55	55 55 55 55 55 55 55	
11	1 0010	001	77 77 77	77 77 77 77 77 77 77	
12	1 0010	010	BB BB BB	BB BB BB BB BB BB BB	
13	1 0010	011	DD DD DD	DD DD DD DD DD DD DD	
14	1 0010	100	EE EE EE	EE EE EE EE EE EE EE	
15	1 0010	101	AA AA AA	AA AA AA AA AA AA AA	
16	1 0010	110	55 55 55	55 55 55 55 55 55 55	
17	1 0010	111	AA AA AA	AA AA AA AA AA AA AA	

Note: *The "PI" subfield of the Message must be properly generated in accordance with §2.2.3.2.1.7.*

Verify that each message provided to the ADS-B and TIS-B Receiver results in an Output Message that is delivered to the user interface or Report Assembly function in not more than 2.0 milliseconds after receipt of the last message bit of each message. Verify that the Output Message format for each message is consistent with the requirements of §2.2.6.1.1 (for ADS-B) and §2.2.17.2 (for TIS-B), and represent the data provided in the message as specified in Table 2-169.

2.4.7 Verification of the ADS-B Message Processor Characteristics (§2.2.7)

No specific test procedure is required to validate §2.2.7.

2.4.7.1 Verification of the ADS-B Receiving Device Message Reception (§2.2.7.1)

Appropriate test procedures to validate the requirements of this section are provided in §2.4.8.1, §2.4.8.2, §2.4.8.3, all subsections inclusive.

2.4.7.1.1 Verification of the Receipt of TYPE Code Equal to ZERO (§2.2.7.1.1)

Purpose/Introduction:

An ADS-B Message containing TYPE Code ZERO can only be used to update the altitude data of an aircraft that is already being tracked by the entity receiving the altitude data in TYPE Code ZERO ADS-B Message.

If an ADS-B Message with TYPE Code equal to ZERO is received, it should be checked to see if altitude data is present and then process the altitude data as follows:

a. If altitude data is not present, the message is discarded.

b. If altitude data is present, it may be used to update altitude as needed.

Measurement Procedure:

Appropriate test procedures to validate the requirements of this section are provided in §2.4.10.4.1.3.

2.4.8 Verification of the ADS-B Report Characteristics (§2.2.8)

All tests in §2.4.8 and its subsections using 1090ES ADS-B Messages as input must include ADS-B Messages with “TYPE” Codes 24 – 27 and 30 in order to verify that these ADS-B Message types do not adversely impact report assembly.

a. At least 35% of the “TYPE Code” 24 – 27 and 30 ADS-B Messages **shall** have addresses (AA) that are the same as at least one of the simulated target addresses in any one test.

b. At least 35% of the "TYPE Code" 24 – 27 and 30 ADS-B Messages **shall** have addresses (AA) that are NOT the same as the addresses of the simulated targets used in a test.

c. At least one of the "TYPE Code" 24 – 27 and 30 ADS-B Messages **shall** be scheduled to arrive during each Report Assembly State (ref §2.2.10.1.1) achieved during the test.

Appropriate test procedures required to validate the requirements of §2.2.8 are included in the following subparagraphs.

2.4.8.1 Verification of the ADS-B State Vector Report Characteristics (§2.2.8.1)

Appropriate test procedures required to validate the requirements of §2.2.8.1 are included in the following subparagraphs.

2.4.8.1.1 Verification of the State Vector Report Type and Structure Identification and Validity Flags (§2.2.8.1.1)

No specific test procedure is required to validate §2.2.8.1.1.

2.4.8.1.1.1 Verification of the State Vector Report Type and Structure Identification (§2.2.8.1.1.1)

Purpose/Introduction:

The Report Type is used to identify the type of ADS-B Report being generated by the report generation function and being provided to the User Application. The Report Type formats and maximum number of bytes to be contained in each report are identified in Table 2-82. The Report Structure field is used to indicate the exact data parameters identified in Table 2-81 that are being provided in the State Vector Report and is intended to provide a methodology for the report processor to structure shorter reports when data for some parameters, or groups of parameters, are not available. The basic conventions for providing shorter reports are provided in §2.2.8.1.1.1.

Measurement Procedure:

For each case in Table 2-170 below, execute Step 1 followed by Step 2 with the input simulating ADS-B Messages conforming to RTCA DO-260, as specified in Appendix N, and referenced as "Version Zero (0)" Messages. Repeat each case with the input simulating ADS-B Messages conforming to these MOPS (RTCA DO-260A) and referenced as "Version One (1)" Messages. Repeat each case again with the input simulating ADS-B Messages conforming to these MOPS (RTCA DO-260B) and referenced as "Version Two (2)" Messages. With Version Zero, Version One and Version Two Message receptions, only ADS-B Reports conformant to these MOPS should be generated with the Version Number correctly reported for the individual Participant.

Step 1: Verification of Report Structure Bit Function (§2.2.8.1.1.1.a-c)

Generate a Test Message Type (column 1), which includes the encoded data representing any valid case of the corresponding Parameter Datum (column 2), command the ADS-B Receiver/Report Assembly to output State Vector Reports of Type 0001, and set to "ONE" the corresponding Structure Coding Bit (column 3).

Verify that the Structure Coding Bit, and the Validity Flag Bit (if specified in column 4), for the corresponding Parameter Datum, are "ONEs."

Verify that the Binary Decoded Parameter Datum appears in its proper position in the Report (column 5), and in the proper binary format as specified in Table 2-81 (§2.2.8.1).

Step 2: Verification of Report Structure Bit Function (§2.2.8.1.1.1.a-c)

Repeat Step 1 while implementing the following changes:

Set the Structure Coding Bit, and the Validity Flag, to "ZERO."

Verify that the Structure Coding Bit, and the Validity Flag Bit, are both "ZEROs."

Verify that the Binary Decoded Parameter Datum no longer appears in the Report.

Table 2-170: Report Structure Identification Bit Test Data

Report Structure Identification Bit Coding							
Column 1	**Column 2**	**Column 3**		**Column 4**		**Column 5**	
Test Message Type	**Parameter Data Type**	**State Vector Report Test Fields**					
		Structure Coding		**Validity Flag**		**Parameter Reported In**	
		Byte	**Bit**	**Byte**	**Bit**	**Bytes**	**#Bits**
Airborne Position	Position Time of Applicability	0	2	N/A	N/A	9-14	48
Airborne Velocity - Type 1	Velocity Time of Applicability	0	1	N/A	N/A	9-14	48
Airborne Position	Latitude (WGS-84)	0	0	3	7	15-17	24
Airborne Position	Longitude (WGS-84)	0	0	3	7	18-20	24
Airborne Position	Altitude, Geometric (WGS-84)	1	7	3	6	21-23	24
Airborne Velocity - Type 1	North/South Velocity	1	6	3	5	24-25	16
Airborne Velocity - Type 1	East/West Velocity	1	6	3	5	26-27	16
Surface Position	Movement (i.e., Ground Speed)	1	5	3	4	28	8
Surface Position	Heading while on the surface	1	4	3	3	29	8
Airborne Position	Altitude, Barometric (Pressure)	1	3	3	2	30-32	24
Airborne Velocity - Type 1	Vertical Rate, Geometric (WGS-84)	1	2	3	1	33-34	16
Airborne Velocity - Type 1	Barometric Altitude Rate	1	2	3	1	33-34	16
Airborne Position	NIC	1	1	N/A	N/A	35	4
Airborne Position	Estimated Latitude (WGS-84)	1	0	3	0	36-38	24
Airborne Position	Estimated Longitude (WGS-84)	2	7	3	0	39-41	24
Airborne Velocity - Type 1	Estimated North/South Velocity	2	6	4	7	42-43	16
Airborne Velocity - Type 1	Estimated East/West Velocity	2	5	4	7	44-45	16
Airborne Position & Airborne Velocity	Surveillance Status / Discretes (for Report Formatting see §2.2.8.1.21)	2	4	N/A	N/A	46 46	4 4
Any Message Type	Report Mode	2	3	N/A	N/A	47	2
Not Applicable	**Reserved For Future Expansion**	2	0-2	N/A	N/A	N/A	N/A

2.4.8.1.1.2 Verification of State Vector Report Validity Flags Reporting (§2.2.8.1.1.2)

Appropriate test procedures provided in §2.4.8.1.5 through §2.4.8.1.20 **shall** be used to validate the reporting of validity flags.

2.4.8.1.2 Verification of the Participant Address (§2.2.8.1.2)

Appropriate test procedures to validate the Participant Address (§2.2.3.2.1.5) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.8.1.3 Verification of the Address Qualifier (§2.2.8.1.3)

Purpose/Introduction:

The Address Qualifier subfield is used to indicate the type of Participant Address (§2.2.3.2.1.5) being reported and the encoding is specified in Table 2-85.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to ONE (binary 0001) to indicate State Vector Report.

Step 2: Verification of ICAO Address for Unknown Emitter

Input an ADS-B Aircraft Identification and Category Message where an ICAO address is being reported as the Participant Address for an unknown emitter category.

Verify that the three least significant bits of Byte 8 in the output report are set to ALL ZEROs (binary 000).

Step 3: Verification of Non-ICAO Address for Unknown Emitter

Input an ADS-B Aircraft Identification and Category Message where a Non-ICAO address is being reported as the Participant Address for an unknown emitter category.

Verify that the three least significant bits of Byte 8 in the output report are set to ONE (binary 001).

Step 4: Verification of ICAO Address for an Aircraft

Input an ADS-B Aircraft Identification and Category Message where an ICAO address is being reported as the Participant Address for an aircraft.

Verify that the three least significant bits of Byte 8 in the output report are set to TWO (binary 010).

Step 5: Verification of Non-ICAO Address for an Aircraft

Input an ADS-B Aircraft Identification and Category Message where a Non-ICAO address is being reported as the Participant Address for an aircraft.

Verify that the three least significant bits of Byte 8 in the output report are set to THREE (binary 011).

Step 6: Verification of ICAO Address for a Surface Vehicle, Fixed Ground or Tethered Obstruction

Input an ADS-B Aircraft Identification and Category Message where an ICAO address is being reported as the Participant Address for a surface vehicle, a fixed ground or a tethered obstruction.

Verify that the three least significant bits of Byte 8 in the output report are set to FOUR (binary 100).

Step 7: Verification of Non-ICAO Address for a Surface Vehicle, Fixed Ground or Tethered Obstruction

Input an ADS-B Aircraft Identification and Category Message where a Non-ICAO address is being reported as the Participant Address for a surface vehicle, a fixed ground or a tethered obstruction.

Verify that the three least significant bits of Byte 8 in the output report are set to FIVE (binary 101).

2.4.8.1.4 Verification of the Report Time of Applicability (§2.2.8.1.4)

Appropriate test procedures required to validate the requirements of §2.2.8.1.4 are included in the following subparagraphs.

2.4.8.1.4.1 Verification of the Time of Applicability for Estimated Position/Velocity (§2.2.8.1.4.1)

Purpose/Introduction:

The Time of Applicability for the estimated position and velocity is generated under the conditions specified in §2.2.8.1.4.1.

Measurement Procedure:

Step 1: Verification of (TOA) for Estimated Position and Velocity Reporting – Position Updates

Within a ten (10) second period, generate a series of **"even"** and **"odd"** Airborne Position Messages having a stable TYPE code which include encoded data ("ME" Bits 23 – 39 for Latitude, and Bits 40 – 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position and any valid velocity. Verify that the Report Assembly Function outputs a State Vector Report with the Time of Applicability for Position and Velocity Subfields updated to reflect the data in the most recently received Airborne Position Message.

Update the State Vector Report as specified in §2.2.8.1.17 and §2.2.8.1.18 and, in each case, verify that the Time of Applicability for Estimated Position and Velocity presence bit, bit 3 of byte 0 (Table 2-83), is set to ONE (1), that the Horizontal Position Validity Flag, bit 7 of byte 3 (Table 2-84), is set to ONE (1), that the Airborne Horizontal Velocity Validity Flag, bit 5 of byte 3, is set to ONE (1), and that the corresponding Estimated Time of Applicability for Position and Velocity Subfield reflects these updates in the next output State Vector Report.

Repeat this step with the Time of Applicability for Estimated Position and Velocity presence bit, bit 3 of byte 0, set to ONE (1), the Horizontal Position Validity Flag, bit 7 of byte 3, set to ONE (1), and the Airborne Horizontal

Velocity Validity Flag, bit 5 of byte 3, set to ZERO (0). Verify that the Estimated Time of Applicability for Position and Velocity Subfield is set to ALL ZEROs in the next output State Vector Report.

Repeat this step with the Time of Applicability for Estimated Position and Velocity presence bit, bit 3 of byte 0, set to ONE (1), the Horizontal Position Validity Flag, bit 7 of byte 3, set to ZERO (0), and the Airborne Horizontal Velocity Validity Flag, bit 5 of byte 3, set to ONE (1). Verify that the Estimated Time of Applicability for Position and Velocity Subfield is set to ALL ZEROs in the next output State Vector Report.

Step 2: Verification of (TOA) for Estimated Position and Velocity Reporting – Velocity Updates

Within a ten (10) second period, generate a series of **"even"** and **"odd"** Airborne Position Messages having a stable TYPE code which include encoded data ("ME" Bits 23 – 39 for Latitude, and Bits 40 – 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position and any valid velocity. Verify that the Report Assembly Function outputs a State Vector Report with the Time of Applicability for Position and Velocity Subfields updated to reflect the data in the most recently received Airborne Position Message.

Update the State Vector Report as specified in §2.2.8.1.19 and §2.2.8.1.20 and, in each case, verify that the Time of Applicability for Estimated Position and Velocity presence bit, bit 3 of byte 0, is set to One (1), that the Horizontal Position Validity Flag, bit 7 of byte 3, is set to One (1), that the Airborne Horizontal Velocity Validity Flag, bit 5 of byte 3, is set to ONE (1), and that the corresponding Estimated Time of Applicability for Position and Velocity Subfield reflects these updates in the next output State Vector Report.

Repeat this step with the Time of Applicability for Estimated Position and Velocity presence bit, bit 3 of byte 0, set to ONE (1), the Horizontal Position Validity Flag, bit 7 of byte 3, set to ONE (1), and the Airborne Horizontal Velocity Validity Flag, bit 5 of byte 3, set to ZERO (0). Verify that the Estimated Time of Applicability for Position and Velocity Subfield is set to ALL ZEROs in the next output State Vector Report.

Repeat this step with the Time of Applicability for Estimated Position and Velocity presence bit, bit 3 of byte 0, set to ONE (1), the Horizontal Position Validity Flag, bit 7 of byte 3, set to ZERO (0), and the Airborne Horizontal Velocity Validity Flag, bit 5 of byte 3, set to ONE (1). Verify that the Estimated Time of Applicability for Position and Velocity Subfield is set to ALL ZEROs in the next output State Vector Report.

Step 3: Verification of (TOA) for Estimated Position (resulting from received Surface Position Messages) Reporting

Within a ten (10) second period, generate a series of **"even"** and **"odd"** Surface Position Messages having a stable TYPE code which include encoded data ("ME" Bits 23 – 39 for Latitude, and Bits 40 – 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position, and which include encoded data (“ME” Bits 6 – 12) for a Ground Speed (Movement) of 2 knots (forces “High” rate of two Surface Position Messages per second). Verify that the Report Assembly Function outputs a State Vector Report with the Report Mode set to TWO (binary xxxx 0010) within 500 milliseconds of receipt of the second Surface Position Message of the **“even”** and **“odd”** pair for the given Surface Participant.

Update the State Vector Report as specified in §2.2.8.1.17, §2.2.8.1.18, §2.2.8.1.19 and §2.2.8.1.20 and, in each case, verify that the corresponding Position Time of Applicability bit (Report Byte #2, Bit 1), and the Latitude and Longitude Validity Flag (Report Byte #4, Bit 7), are both set to “ONE.”

Verify that the reported Binary Decoded Position Time of Applicability datum (Report Bytes # 40 – 41) changes by less than 500 ms between reports.

Step 4: Verification of (TOA) for Estimated Velocity (resulting from received Surface Position Messages) Reporting

Repeat step 3 and verify that the Report Assembly Function outputs a State Vector Report with the Report Mode set to TWO (binary xxxx 0010). Generate a series of **“even”** and **“odd”** Surface Position Messages having a stable TYPE code, which include encoded data (“ME” Bits 6 – 12) for a Ground Speed (Movement) of 2 knots (forces “High” rate of two Surface Position Messages per second), and a Ground Track Status (“ME” Bit 13) of “ONE,” and encoded data (“ME” Bits 14 – 20) for any convenient Ground Track heading.

Update the State Vector Report as specified in §2.2.8.1.17, §2.2.8.1.18, §2.2.8.1.19 and §2.2.8.1.20 and, in each case, verify that the corresponding Velocity Time of Applicability presence bit (Report Byte #2, Bit 0), Ground Speed Validity Flag (Report Byte #4, Bit 0), and Ground Track Validity Flag (Report Byte #5, Bit 7), are both set to “ONE.”

Verify that the reported Binary Decoded Velocity Time of Applicability datum changes by less than 500 ms between reports.

2.4.8.1.4.2 Verification of the Position Time of Applicability (§2.2.8.1.4.2)

Appropriate test procedures required to validate the requirements of §2.2.8.1.4.2 are included in the following subparagraphs.

2.4.8.1.4.2.1 Verification of Position Time of Applicability when “TIME” (T)=0 (§2.2.8.1.4.2.1)

Purpose/Introduction:

These test procedures verify that each time an Airborne or Surface Position Message is received with valid Latitude ***AND*** Longitude data and “TIME” (T)=0, the Report Assembly Function updates the Position Time of Applicability data in the State Vector Report with the Time of Message Receipt of the position message expressed as either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2).

Time of Applicability is rounded to the nearest LSB of the Position Time of Applicability field.

Equipment Required:

The unit under test must be capable of receiving messages and producing State Vector Reports. A stimulus capable of forming and transmitting compliant 1090ES Messages at specific times and an apparatus for analyzing State Vector Report contents are required.

Measurement Procedure:

Step 1: Position Time of Applicability for Airborne Position Messages When “TIME” (T)=0

Generate a series of Airborne Position Messages per Table 2-171 which have a stable TYPE Code and include encoded data (“ME” Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position. The latitude and longitude in each message **shall** be unique among the latitudes and longitudes used in the set of messages.

Ensure that the unit under test does not have a track file for the target address used in the Airborne Position Messages. Inject the Airborne Position Messages into the unit under test at the times shown in the “Receiver Input Time” column of Table 2-171. Verify that the difference in Position TOA between State Vector Reports matches the value in the “TOA Difference Between Reports” column of Table 2-171 rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report matches the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each Airborne Position Message.

Note: *The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.5 using the latitudes and longitudes that were CPR encoded into the Airborne Position Messages.*

Table 2-171: Position Message Contents for Position TOA Verification When T=0

CPR Format (F)	Receiver Input Time (UTC sec)	TOA Difference Between Reports	Comment
0	t_0	No Report	
1	$t_0 + 0.5$	First Report	First global decode complete
0	$t_0 + 0.9$	0.40	
1	$t_0 + 1.5$	0.60	Second global decode complete
1	$t_0 + 2.05$	0.55	
0	$t_0 + 2.55$	0.50	

Step 2: Position Time of Applicability for Surface Position Messages When "TIME" (T)=0

Repeat Step 1 using Surface Position Messages. Verify that the difference in Position TOA between State Vector Reports matches the value in the "TOA Difference Between Reports" column of Table 2-171-A rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report matches the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each Surface Position Message.

Note: *The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.6 using the latitudes and longitudes that were CPR encoded into the Surface Position Messages.*

2.4.8.1.4.2.2 Verification of Position Time of Applicability When "TIME" (T)=1 and UTC Time of Message Receipt is Available (§2.2.8.1.4.2.2)

Purpose/Introduction:

These test procedures verify that each time an Airborne or Surface Position Message is received with "TIME" (T)="1" and valid Latitude AND Longitude data, and when a valid UTC Time of Message Receipt is available per §2.2.8.5.1, the Report Assembly Function updates the Position Time of Applicability data in the State Vector Report with the appropriate 0.2 second UTC epoch.

Equipment Required:

The unit under test must be provided with a UTC time reference, and must be capable of receiving messages and producing State Vector Reports. A stimulus capable of forming and transmitting compliant 1090ES Messages at specific UTC times and a UTC time reference for this stimulus are required. An apparatus for capturing State Vector Reports and analyzing their contents is also required.

Measurement Procedure:

Step 1: Position Time of Applicability for Airborne Position Messages When "TIME" (T)=1 and UTC Time of Message Receipt is Available

Generate a series of Airborne Position Messages per Table 2-171-A which have a stable TYPE Code and include encoded data ("ME" Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position. The latitude and longitude in each message **shall** be unique among the latitudes and longitudes used in the set of messages.

Ensure that the unit under test does not have a track file for the target address used in the Airborne Position Messages. Inject the Airborne Position Messages into the unit under test at the times shown in the "Receiver Input Time" column of Table 2-171-A. Verify that the Position TOA in the State Vector Reports matches the value in the "Expected Position TOA" column of Table 2-171-A rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report matches the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each Airborne Position Message.

Note: *The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.5 using the latitudes and longitudes that were CPR encoded into the Airborne Position Messages.*

Table 2-171-A: Messages for Position TOA Verification when T=1

TOA of Lat/Lon in Position Message	CPR Format (F)	Receiver Input Time (UTC sec)	Expected Position TOA	Comment
t_{even} + 0	0	t_{even} + 0	No Report	
t_{even} + 0.6	1	t_{even} + 0.5	t_{even} + 0.6	First global decode complete
t_{even} + 0.8	0	t_{even} + 0.9	t_{even} + 0.8	
t_{even} + 1.4	1	t_{even} + 1.5	t_{even} + 1.4	Second global decode complete
t_{even} + 2.2	1	t_{even} + 2.05	t_{even} + 2.2	New data loaded and transmitted at the beginning of the 50-150ms window
t_{even} + 2.4	0	t_{even} + 2.55	t_{even} + 2.4	Old data transmitted at the end of the 50-150 ms window just before loading of new data

Note: *t_{even} is any integer UTC second.*

Step 2: Position Time of Applicability for Surface Position Messages When "TIME" (T)=1 and UTC Time of Message Receipt is Available

Repeat Step 1 using Surface Position Messages. Verify that the Position TOA in the State Vector Reports matches the value in the "Expected Position TOA" column of Table 2-171-A rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report matches the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each Surface Position Message.

Note: *The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.6 using the latitudes and longitudes that were CPR encoded into the Surface Position Messages.*

2.4.8.1.4.2.3 Verification of Position Time of Applicability when "TIME" (T) = "1" and UTC Time of Message Receipt is NOT available (§2.2.8.1.4.2.3)

The requirement in §2.2.8.1.4.2.3 is verified using the test procedure specified in §2.4.8.1.4.2.1.

2.4.8.1.4.3 Verification of the Velocity Time of Applicability (§2.2.8.1.4.3)

Purpose/Introduction:

These test procdures verify that each time an Airborne Velocity Message - Subtype=1 or "2" is received with valid East/West ***AND*** North/South Velocity data, the Report Assembly Function updates the Velocity Time of Applicability data in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

These test procedures also verify that each time a Surface Position Message is received with valid Movement ***AND*** Ground Track data, the Report Assembly Function updates the Velocity Time of Applicability data in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Measurement Procedure:

Step 1: Velocity Time of Applicability Updating and Reporting (resulting from received Airborne Velocity Messages - Subtype=1) Reporting

Repeat Step 1 of §2.2.8.1.4.2 and verify that the Report Assembly Function outputs a State Vector Report with the Report Mode set to ONE (binary xxxx 0001). Generate an Airborne Velocity Message (TYPE=19, Subtype=1), which includes encoded data ("ME" Bits 14 - 24 for E/W Velocity, and "ME" Bits 25 - 35 for N/S Velocity) based on any convenient valid velocity. Verify that the Report Assembly Function outputs a State Vector Report with the Report Mode set to TWO (binary xxxx 0010) within 500 milliseconds of the receipt of the Airborne Velocity Message.

Verify that the corresponding Velocity Time of Applicability presence bit (Report Byte #2, Bit 0), and the N/S & E/W Velocity Validity Flag (Report Byte #4, Bit 5), are set to "ONEs." Verify that the Velocity Time of Applicability presence bit, bit 1 of byte 2, is set to ONE (1).

Verify that the reported Binary Decoded Velocity Time of Applicability datum (Report Bytes # 42 - 43) changes by less than 500 ms between reports. Table 2-172 below shows an example of a possible time progression from a series of reports.

Repeat this step with the Velocity Time of Applicability presence bit, bit 1 of byte 2, set to ONE (1) and the N/S & E/W Validity Flag, bit 5 of byte 3, set to ZERO (0). Verify that the Velocity Time of Applicability Subfield is set to ALL ZEROs in the next output State Vector Report.

<u>Table 2-172:</u> Velocity Time of Applicability Example Test Data

Velocity Time of Applicability	
Example Time (seconds)	**Binary Decoded Velocity Time of Applicability**
Reference Time	0101 0101 0101 0110
Reference Time + Approximately 0.5	0101 0101 1001 0010
Reference Time + Approximately 1.0	0101 0101 1101 0111
Reference Time + Approximately 1.5	0101 0110 0001 0110
Reference Time + Approximately 2.0	0101 0110 0101 0011

<u>Step 2:</u> <u>Velocity Time of Applicability Updating and Reporting (resulting from received Surface Position Messages)</u>

Repeat Step 2 of §2.2.8.1.4.2 and verify that the Report Assembly Function outputs a State Vector Report with the Report Mode set to TWO (binary xxxx 0010). Generate a series of "**even**" and "**odd**" Surface Position Messages having a stable TYPE code, which include encoded data ("ME" Bits 6 - 12) for a Ground Speed (Movement) of 2 knots (forces "High" rate of two Surface Position Messages per second), which include a Ground Track Status ("ME" Bit 13) of "ONE," and which include encoded data ("ME" Bits 14 - 20) for any convenient Ground Track heading.

Verify that the corresponding Velocity Time of Applicability presence bit (Report Byte #2, Bit 0), Ground Speed validity flag (Report Byte #4, Bit 0), and Ground Track validity flag (Report Byte #5, Bit 7), are set to "ONEs." Verify that the Velocity Time of Applicability presence bit, bit 1 of byte 2, is set to ONE (1).

Verify that the reported Binary Decoded Velocity Time of Applicability datum changes by less than 500 ms between reports. Table 2-172 above shows an example of a possible time progression from a series of reports.

Repeat this step with the Velocity Time of Applicability presence bit, bit 1 of byte 2, set to ONE (1) and the N/S & E/W Validity Flag, bit 5 of byte 3, set to ZERO (0). Verify that the Velocity Time of Applicability Subfield is set to ALL ZEROs in the next output State Vector Report.

2.4.8.1.5 Verification of Latitude (WGS-84) Reporting (§2.2.8.1.5)

<u>Purpose/Introduction:</u>

These test procedures verify that the ADS-B Report Assembly Function decodes the Encoded Latitude data (§2.2.3.2.3.7 and /or §2.2.3.2.4.7) provided in the ADS-B broadcast. Decoding of the encoded latitude data is performed in accordance with §A.1.7.4 through §A.1.7.8.4 of Appendix A. Latitude data is provided to the user application in the State Vector report in angular weighted binary format (M bit = 90 degrees, S bit = negative, or 180 degrees) as specified in Table 2-81.

When valid encoded latitude data is not available, the latitude data provided to the user application is set to ALL ZEROs, and the Horizontal Position Validity Flag bit, i.e., bit #7

(MSB) of byte #3 of the State Vector Report, is set to ZERO (0) to indicate that the reported Horizontal Position data is not valid. Otherwise, the Horizontal Position Validity Flag bit, i.e., bit #7 (MSB) of byte #3 of the State Vector Report, is set to ONE (1), unless modified by other conditions.

Measurement Procedure:

Step 1: Latitude (WGS-84) Decoding

For each case in Table 2-174 below, generate valid Airborne Position Messages that include the encoded data (“ME” Bits 23 - 39) for the Decimal Latitude value listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Report of Type 0001.

Verify that the corresponding Latitude presence bit (Report Byte #0, Bit 0), and the Horizontal Position Validity flag (Report Byte #3, Bit 7), are “ONEs.”

Verify that the reported Binary Decoded (WGS-84) Latitude datum match the corresponding value in the table.

Table 2-173: Longitude Test Data

Longitude		
Decimal Longitude (degrees)	**Integer Longitude (degrees)**	**Binary Decoded (WGS-84) Longitude (angular weighted)**
0.000000	0	0000 0000 0000 0000 0000 0000
0.000021	1	0000 0000 0000 0000 0000 0001
0.000043	2	0000 0000 0000 0000 0000 0010
0.000107	5	0000 0000 0000 0000 0000 0101
0.000215	10	0000 0000 0000 0000 0000 1010
0.000429	20	0000 0000 0000 0000 0001 0100
0.000880	41	0000 0000 0000 0000 0010 1001
0.001760	82	0000 0000 0000 0000 0101 0010
0.003541	165	0000 0000 0000 0000 1010 0101
0.007081	330	0000 0000 0000 0001 0100 1010
0.014162	660	0000 0000 0000 0010 1001 0100
0.028324	1320	0000 0000 0000 0101 0010 1000
0.056648	2640	0000 0000 0000 1010 0101 0000
0.113297	5280	0000 0000 0001 0100 1010 0000
0.226593	10560	0000 0000 0010 1001 0100 0000
0.453186	21120	0000 0000 0101 0010 1000 0000
0.906372	42240	0000 0000 1010 0101 0000 0000
1.812744	84480	0000 0001 0100 1010 0000 0000
3.625488	168960	0000 0010 1001 0100 0000 0000
7.250977	337920	0000 0101 0010 1000 0000 0000
14.501953	675840	0000 1010 0101 0000 0000 0000
29.003906	1351680	0001 0100 1010 0000 0000 0000
58.007813	2703360	0010 1001 0100 0000 0000 0000
116.015625	5406720	0101 0010 1000 0000 0000 0000
-127.968750	10813440	1010 0101 0000 0000 0000 0000
104.062500	4849664	0100 1010 0000 0000 0000 0000
-151.875000	9699328	1001 0100 0000 0000 0000 0000
56.250000	2621440	0010 1000 0000 0000 0000 0000
112.500000	5242880	0101 0000 0000 0000 0000 0000
-135.000000	10485760	1010 0000 0000 0000 0000 0000
90.000000	4194304	0100 0000 0000 0000 0000 0000
180.000000	8388608	1000 0000 0000 0000 0000 0000

Step 2: Longitude (WGS-84) Decoding

For each case in Table 2-173 above, generate valid Airborne Position Messages that include the encoded data ("ME" Bits 40 - 56) for the Decimal Longitude value listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Longitude presence bit (Report Byte #0, Bit 0), and the Horizontal Position Validity flag (Report Byte #3, Bit 7), are "ONEs."

Verify that the reported Binary Decoded (WGS-84) Longitude datum matches the corresponding value in the table.

Table 2-174: Latitude Test Data

Latitude		
Decimal Latitude (degrees)	**Integer Latitude (degrees)**	**Binary Decoded (WGS-84) Latitude (angular weighted)**
0.000000	0	0000 0000 0000 0000 0000 0000
0.000037	1	0000 0000 0000 0000 0000 0001
0.000073	3	0000 0000 0000 0000 0000 0011
0.000147	6	0000 0000 0000 0000 0000 0110
0.000294	13	0000 0000 0000 0000 0000 1101
0.000587	27	0000 0000 0000 0000 0001 1011
0.001175	54	0000 0000 0000 0000 0011 0110
0.002350	109	0000 0000 0000 0000 0110 1101
0.004699	219	0000 0000 0000 0000 1101 1011
0.009398	438	0000 0000 0000 0001 1011 0110
0.018797	876	0000 0000 0000 0011 0110 1100
0.037594	1752	0000 0000 0000 0110 1101 1000
0.075188	3504	0000 0000 0000 1101 1011 0000
0.150375	7008	0000 0000 0001 1011 0110 0000
0.300751	14016	0000 0000 0011 0110 1100 0000
0.601501	28032	0000 0000 0110 1101 1000 0000
1.203003	56064	0000 0000 1101 1011 0000 0000
2.406006	112128	0000 0001 1011 0110 0000 0000
4.812012	224256	0000 0011 0110 1100 0000 0000
9.624023	448512	0000 0110 1101 1000 0000 0000
19.248047	897024	0000 1101 1011 0000 0000 0000
38.496094	1794048	0001 1011 0110 0000 0000 0000
76.992188	3588096	0011 0110 1100 0000 0000 0000
-52.031250	14352384	1101 1011 0000 0000 0000 0000
-56.250000	14155776	1101 1000 0000 0000 0000 0000
-90.000000	12582912	1100 0000 0000 0000 0000 0000

Step 3: Latitude and Longitude Data Not Available

Keep the Latitude and Longitude presence bits at “ONE,” and set the Horizontal Position Validity flag to “ZERO.” Verify that the reported Binary Decoded Latitude and Longitude data are set to all “ZEROs.”

2.4.8.1.6 Verification of Longitude (WGS-84) Reporting (§2.2.8.1.6)

Appropriate test procedures to validate the requirements of §2.2.8.1.6 are provided in §2.4.8.1.5.

2.4.8.1.7 Verification of Altitude, Geometric (WGS-84) Reporting (§2.2.8.1.7)

Purpose/Introduction:

These test procedures verify the proper reporting of altitude date as specified in §2.2.8.1.7.

Measurement Procedure:

Step 1: Geometric Altitude (WGS-84) Reporting for “Q” Bit =“ONE” (§2.2.8.1.7.a & .c)

For each case in Table 2-175 below, generate valid Airborne Position Messages, with “TYPE” codes of 20 through 22, which include the encoded datum (“ME” Bits 9 - 20) for the Decimal Altitude value listed, with an imbedded “**Q**” bit (“ME” Bit 16) of “ONE,” and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Geometric Altitude presence bit (Report Byte #1, Bit 7), and Geometric Altitude Validity Flag (Report Byte #3, Bit 6), are “ONEs.”

Verify that the reported Binary Decoded (WGS-84) Geometric Altitude datum (Report Bytes # 21 – 23) matches the corresponding value in the table.

Table 2-175: Geometric Altitude Test Data (Q Bit = 1)

Geometric (WGS-84) Altitude ("Q" Bit = 1)		
Decimal Altitude (feet)	**Integer Altitude (Binary)**	**Binary Decoded (WGS-84) Geometric Altitude**
-1000	-64000	1111 1111 0000 0110 0000 0000
-975	-62400	1111 1111 0000 1100 0100 0000
-925	-59200	1111 1111 0001 1000 1100 0000
-825	-52800	1111 1111 0011 0001 1100 0000
-625	-40000	1111 1111 0110 0011 1100 0000
-575	-36800	1111 1111 0111 0000 0100 0000
-500	-32000	1111 1111 1000 0011 0000 0000
-225	-14400	1111 1111 1100 0111 1100 0000
-200	-12800	1111 1111 1100 1110 0000 0000
-125	-8000	1111 1111 1110 0000 1100 0000
-25	-1600	1111 1111 1111 1001 1100 0000
0	0	0000 0000 0000 0000 0000 0000
25	1600	0000 0000 0000 0110 0100 0000
50	3200	0000 0000 0000 1100 1000 0000
100	6400	0000 0000 0001 1001 0000 0000
200	12800	0000 0000 0011 0010 0000 0000
400	25600	0000 0000 0110 0100 0000 0000
800	51200	0000 0000 1100 1000 0000 0000
1600	102400	0000 0001 1001 0000 0000 0000
3200	204800	0000 0011 0010 0000 0000 0000
6400	409600	0000 0110 0100 0000 0000 0000
12800	819200	0000 1100 1000 0000 0000 0000
25600	1638400	0001 1001 0000 0000 0000 0000
49175	3147200	0011 0000 0000 0101 1100 0000
49200	3148800	0011 0000 0000 1100 0000 0000
50175	3211200	0011 0000 1111 1111 1100 0000

Step 2: Geometric Altitude (WGS-84) Reporting for "**Q**" Bit ="ZERO" (§2.2.8.1.7.a &.c)

For each case in Table 2-176 below, generate valid Airborne Position Messages, with "Type" codes of 20 through 22, which include the encoded datum ("ME" Bits 9 - 20) for the Decimal Altitude value listed, with an imbedded "**Q**" bit ("ME" Bit 16) of "ZERO," and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Geometric Altitude presence bit (Report Byte #1, Bit 7), and Geometric Altitude Validity Flag (Report Byte #3, Bit 6), are set to "ONEs."

Verify that the reported Binary Decoded (WGS-84) Geometric Altitude datum (Report Bytes # 21 – 23) matches the corresponding value in the table.

Table 2-176: Geometric Altitude Test Data (Q Bit = 0)

Geometric (WGS-84) Altitude ("Q" Bit = 0)		
Decimal Altitude (feet)	**Integer Altitude (Binary)**	**Binary Decoded (WGS-84) Geometric Altitude**
-1000	-64000	1111 1111 0000 0110 0000 0000
-800	-51200	1111 1111 0011 1000 0000 0000
-100	-6400	1111 1111 1110 0111 0000 0000
0	0	0000 0000 0000 0000 0000 0000
100	6400	0000 0000 0001 1001 0000 0000
200	12800	0000 0000 0011 0010 0000 0000
400	25600	0000 0000 0110 0100 0000 0000
800	51200	0000 0000 1100 1000 0000 0000
1600	102400	0000 0001 1001 0000 0000 0000
3200	204800	0000 0011 0010 0000 0000 0000
6400	409600	0000 0110 0100 0000 0000 0000
12800	819200	0000 1100 1000 0000 0000 0000
25600	1638400	0001 1001 0000 0000 0000 0000
51200	3276800	0011 0010 0000 0000 0000 0000
102400	6553600	0110 0100 0000 0000 0000 0000
126700	8108800	0111 1011 1011 1011 0000 0000

Step 3: Barometric Altitude (WGS-84) Reporting for "Q" Bit ="ONE" (§2.2.8.1.7.b &.c)

For each case in Table 2-175 above**,** generate valid Airborne Position Messages, with "Type" codes of 9 through 18, which include the encoded datum ("ME" Bits 9 - 20) for the Decimal Altitude value listed, with an imbedded "**Q**" bit ("ME" Bit 16) of "ONE," and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Barometric Altitude presence bit (Report Byte #1, Bit 3), and Barometric Altitude Validity Flag (Report Byte #3, Bit 2), are "ONEs."

Verify that the reported Binary Decoded (WGS-84) Barometric Altitude datum (Report Bytes # 30 – 32) matches the corresponding value in the table.

Step 4: Barometric Altitude (WGS-84) Reporting for "**Q**" Bit = "ZERO" (§2.2.8.1.7.b&c)

For each case in Table 2-176 above**,** generate valid Airborne Position Messages, with "Type" codes of 9 through 18, which include the encoded datum ("ME" Bits 9 - 20) for the Decimal Altitude value listed, with an imbedded "**Q**" bit ("ME" Bit 16) of "ZERO," and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Barometric Altitude presence bit (Report Byte #1, Bit 3), and Barometric Altitude Validity Flag (Report Byte #3, Bit 2), are "ONEs."

Verify that the reported Binary Decoded (WGS-84) Barometric Altitude datum (Report Bytes # 30 – 32) matches the corresponding value in the table.

Step 5: Difference from Barometric Altitude Reporting (§2.2.8.1.7.b)

For each case in Table 2-177 below, generate valid Airborne Velocity Messages, with TYPE=19, and Subtype=1, which includes the encoded data (Difference from Barometric Altitude Sign, "ME" bit 49, and Difference from Barometric Altitude, "ME" Bits 50 - 56) resulting from using the Decimal GNSS Altitude and Decimal Barometric Altitude values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Difference From Barometric Altitude presence bit (Report Byte #1, Bit 7), and Geometric Altitude Validity Flag (Report Byte #3, Bit 6), are "ONEs."

Verify that the reported Binary Decoded (WGS-84) Difference from Barometric Altitude datum matches the corresponding value in the table.

Repeat this procedure for Velocity Message Subtypes 2, 3 and 4.

Table 2-177: Difference From Barometric Altitude (w/ Sign) Test Data

Difference From Barometric Altitude			
Decimal GNSS Altitude (feet)	**Decimal Barometric Altitude (feet)**	**Decimal Difference (feet)**	**Binary Decoded (WGS-84) Difference from Barometric**
100	3250	-3150	1111 1111 1001 1101 1001 0000
100	1700	-1600	1111 1111 1100 1110 0000 0000
100	900	-800	1111 1111 1110 0111 0000 0000
100	500	-400	1111 1111 1111 0011 1000 0000
100	300	-200	1111 1111 1111 1001 1100 0000
100	200	-100	1111 1111 1111 1100 1110 0000
100	150	-50	1111 1111 1111 1110 0111 0000
100	125	-25	1111 1111 1111 1111 0011 1000
100	100	0	0000 0000 0000 0000 0000 0000
125	100	25	0000 0000 0000 0000 1100 1000
150	100	50	0000 0000 0000 0001 1001 0000
200	100	100	0000 0000 0000 0011 0010 0000
300	100	200	0000 0000 0000 0110 0100 0000
500	100	400	0000 0000 0000 1100 1000 0000
900	100	800	0000 0000 0001 1001 0000 0000
1700	100	1600	0000 0000 0011 0010 0000 0000
3250	100	3150	0000 0000 0110 0010 0111 0000

Step 6: Geometric Altitude Data Not Available (§2.2.8.1.7.d)

Generate valid ADS-B Airborne Position Messages with the Altitude set to ALL ZEROs to indicate that there is no data available. Verify that the reported Binary Decoded Geometric Altitude data (Report Bytes # 21 – 23) is set to all "ZEROs."

2.4.8.1.8 Verification of North/South Velocity Reporting (§2.2.8.1.8)

Purpose/Introduction:

These test procedures verify the proper reporting of North/South Velocity as specified in §2.2.8.1.8.

Measurement Procedure:

Step 1: North/South Velocity (Subsonic) Reporting (§2.2.8.1.8.a)

For each case in Table 2-178 below, generate valid Airborne Velocity Messages (Subtype 1, Subsonic) which include the encoded Direction Bit and Velocity data ("ME" Bits 25 - 35 for North/South and Bits 14 - 24 for East/West) for the Decimal North/South and Decimal East/West Velocity values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding North/South Velocity presence bit (Report Byte #1, Bit 6), and Airborne Horizontal Velocity Validity Flag (Report Byte #3, Bit 5), are "ONEs."

Verify that the reported Binary Decoded North/South Velocity datum (Report Bytes # 20 - 21) matches the corresponding Binary North/South Velocity value in the table.

Table 2-178: North/South Velocity (Subsonic) Test Data

North/South Velocity (subsonic)		
North/South Decimal Velocity (knots)	**East/West Decimal Velocity (knots)**	**Binary Decoded North/South Subsonic Velocity**
-1021	0	1110 0000 0001 1000
-512	0	1111 0000 0000 0000
-256	0	1111 1000 0000 0000
-128	0	1111 1100 0000 0000
-64	0	1111 1110 0000 0000
-32	0	1111 1111 0000 0000
-16	0	1111 1111 1000 0000
-8	0	1111 1111 1100 0000
-4	0	1111 1111 1110 0000
-2	0	1111 1111 1111 0000
-1	0	1111 1111 1111 1000
0	0	0000 0000 0000 0000
1	0	0000 0000 0000 1000
2	0	0000 0000 0001 0000
4	0	0000 0000 0010 0000
8	0	0000 0000 0100 0000
16	0	0000 0000 1000 0000
32	0	0000 0001 0000 0000
64	0	0000 0010 0000 0000
128	0	0000 0100 0000 0000
256	0	0000 1000 0000 0000
512	0	0001 0000 0000 0000
1021	0	0001 1111 1110 1000

Step 2: North/South Velocity (Supersonic) Reporting (§2.2.8.1.8.a)

For each case in Table 2-179 below, generate valid Airborne Velocity Messages (Subtype 2, Supersonic) which include the encoded Direction Bit and Velocity data ("ME" Bits 25 - 35 for North/South and Bits 14 - 24 for East/West) for the Decimal North/South and Decimal East/West values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding North/South Velocity presence bit (Report Byte #1, Bit 6), and the Airborne Horizontal Velocity Validity Flag (Report Byte #3, Bit 5), are "ONEs."

Verify that the reported Binary Decoded North/South Velocity datum matches the corresponding Binary North/South Velocity value in the table.

Table 2-179: North/South Velocity (Supersonic) Test Data

North/South Velocity (supersonic)		
North/South Decimal Velocity (knots)	**East/West Decimal Velocity (knots)**	**Binary Decoded North/South Supersonic Velocity**
-4084	0	1000 0000 0110 0000
-2048	0	1100 0000 0000 0000
-1024	0	1110 0000 0000 0000
-512	0	1111 0000 0000 0000
-256	0	1111 1000 0000 0000
-128	0	1111 1100 0000 0000
-64	0	1111 1110 0000 0000
-32	0	1111 1111 0000 0000
-16	0	1111 1111 1000 0000
-8	0	1111 1111 1100 0000
-4	0	1111 1111 1110 0000
0	0	0000 0000 0000 0000
4	0	0000 0000 0010 0000
8	0	0000 0000 0100 0000
16	0	0000 0000 1000 0000
32	0	0000 0001 0000 0000
64	0	0000 0010 0000 0000
128	0	0000 0100 0000 0000
256	0	0000 1000 0000 0000
512	0	0001 0000 0000 0000
1024	0	0010 0000 0000 0000
2048	0	0100 0000 0000 0000
4084	0	0111 1111 1010 0000

Step 3: North/South Velocity (Subsonic / Supersonic) Data Not Available (§2.2.8.1.8.b)

Keep the North/South Velocity presence bit at "ONE," and set the North/South Velocity validity flag to "ZERO." Verify that the reported Binary Decoded North/South Velocity datum is set to all "ZEROs."

2.4.8.1.9 Verification of East/West Velocity Reporting (§2.2.8.1.9)

Purpose/Introduction:

These test procedures verify the proper reporting of East/West Velocity as specified in §2.2.8.1.9.

Measurement Procedure:

Step 1: East/West Velocity (Subsonic) Reporting (§2.2.8.1.9.a)

For each case in Table 2-180 below, generate valid Airborne Velocity Messages (Subtype 1, Subsonic) which include the encoded Direction Bit and Velocity data

("ME" Bits 25 - 35 for North/South and Bits 14 - 24 for East/West) for the Decimal North/South and Decimal East/West Velocity values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding East/West Velocity presence bit (Report Byte #1, Bit 6), and the Airborne Horizontal Velocity Validity Flag (Report Byte #3, Bit #5), are "ONEs."

Verify that the reported Binary Decoded East/West Velocity datum (Report Bytes # 22 - 23) matches the corresponding Binary East/West Velocity value in the table.

Table 2-180: East/West Velocity (Subsonic) Test Data

East/West Velocity (subsonic)		
North/South Decimal Velocity (knots)	**East/West Decimal Velocity (knots)**	**Binary Decoded East/West Subsonic Velocity**
0	-1021	1110 0000 0001 1000
0	-512	1111 0000 0000 0000
0	-256	1111 1000 0000 0000
0	-128	1111 1100 0000 0000
0	-64	1111 1110 0000 0000
0	-32	1111 1111 0000 0000
0	-16	1111 1111 1000 0000
0	-8	1111 1111 1100 0000
0	-4	1111 1111 1110 0000
0	-2	1111 1111 1111 0000
0	-1	1111 1111 1111 1000
0	0	0000 0000 0000 0000
0	1	0000 0000 0000 1000
0	2	0000 0000 0001 0000
0	4	0000 0000 0010 0000
0	8	0000 0000 0100 0000
0	16	0000 0000 1000 0000
0	32	0000 0001 0000 0000
0	64	0000 0010 0000 0000
0	128	0000 0100 0000 0000
0	256	0000 1000 0000 0000
0	512	0001 0000 0000 0000
0	1021	0001 1111 1110 1000

Step 2: East/West Velocity (Supersonic) Reporting (§2.2.8.1.9.a)

For each case in Table 2-181 below, generate valid Airborne Velocity Messages (Subtype 2, Supersonic) which include the encoded Direction Bit and Velocity data ("ME" Bits 25 - 35 for North/South and Bits 14 - 24 for East/West) for the Decimal North/South and Decimal East/West values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding East/West Velocity presence bit (Report Byte #1, Bit #6), and the Airborne Horizontal Velocity Validity Flag (Report Byte #3, Bit #5), are "ONEs."

Verify that the reported Binary Decoded North/South Velocity datum matches the corresponding Binary East/West Velocity value in the table.

Table 2-181: East/West Velocity (Supersonic) Test Data

East/West Velocity (supersonic)		
North/South Decimal Velocity (knots)	**East/West Decimal Velocity (knots)**	**Binary Decoded East/West Supersonic Velocity**
0	-4084	1000 0000 0110 0000
0	-2048	1100 0000 0000 0000
0	-1024	1110 0000 0000 0000
0	-512	1111 0000 0000 0000
0	-256	1111 1000 0000 0000
0	-128	1111 1100 0000 0000
0	-64	1111 1110 0000 0000
0	-32	1111 1111 0000 0000
0	-16	1111 1111 1000 0000
0	-8	1111 1111 1100 0000
0	-4	1111 1111 1110 0000
0	0	0000 0000 0000 0000
0	4	0000 0000 0010 0000
0	8	0000 0000 0100 0000
0	16	0000 0000 1000 0000
0	32	0000 0001 0000 0000
0	64	0000 0010 0000 0000
0	128	0000 0100 0000 0000
0	256	0000 1000 0000 0000
0	512	0001 0000 0000 0000
0	1024	0010 0000 0000 0000
0	2048	0100 0000 0000 0000
0	4084	0111 1111 1010 0000

Step 3: East/West Velocity (Subsonic / Supersonic) Data Not Available (§2.2.8.1.9.b)

Keep the East/West Velocity presence bit at "ONE," and set the East/West Velocity validity flag to "ZERO." Verify that the reported Binary Decoded East/West Velocity datum is set to all "ZEROs."

2.4.8.1.10 Verification of Ground Speed Reporting While on the Surface (§2.2.8.1.10)

Purpose/Introduction:

These test procedures verify the proper reporting of Ground Speed as specified in §2.2.8.1.10.

Measurement Procedure:

Step 1: Ground Speed Reporting (§2.2.8.1.10.a)

For each case in Table 2-182 below, generate valid Surface Position Messages ("Type" codes of 5 through 8), which include the encoded datum ("ME" Bits 6 - 12) for the Decimal Ground Speed (Movement) values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Ground Speed (Movement) presence bit (Report Byte #1, Bit #5), and the Ground Speed (Movement) Validity Flag (Report Byte #3, Bit #4), are "ONEs."

Verify that the reported Binary Decoded Ground Speed datum (Report Byte # 35) matches the corresponding value in the table.

Table 2-182: Ground Speed Test Data

Ground Speed	
Decimal Ground Speed (knots)	**Binary Decoded Ground Speed (Movement)**
0.000	0000 0001
0.125	0000 0010
0.250	0000 0011
0.375	0000 0100
0.750	0000 0111
0.875	0000 1000
3.000	0000 1111
3.500	0001 0000
11.000	0001 1111
11.500	0010 0000
39.000	0011 1111
40.000	0100 0000
175.000	0111 1100

Step 2: Ground Speed Data Not Available (§2.2.8.1.10.b)

Keep the Ground Speed (Movement) presence bit at "ONE," and set the Ground Speed (Movement) validity flag to "ZERO." Verify that the reported Binary Decoded Ground Speed (Movement) datum is set to all "ZEROs."

2.4.8.1.11 Verification of Heading While on the Surface Reporting (§2.2.8.1.11)

Purpose/Introduction:

These test procedures verify the proper reporting of Heading while on the surface as specified in §2.2.8.1.11.

Measurement Procedure:

Step 1: Heading Reporting (§2.2.8.1.11.a)

For each case in Table 2-183 below, generate valid Surface Position Messages ("Type" codes of 5 through 8), which include the encoded data ("ME" Bits 13 and 14 - 20) for the Decimal Heading Status Bit and Heading values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Heading presence bit (Report Byte #1, Bit 4), and the Surface Heading Validity Flag (Report Byte #3, Bit 3), are "ONEs."

Verify that the reported Binary Decoded "Heading" data (Report Byte # 36) matches the corresponding value in the table.

Table 2-183: Heading Subfield Test Data

Heading		
Heading Status	**Decimal Heading (degrees)**	**Binary Decoded Heading**
0	22.5000	0000 0000
0	357.1875	0000 0000
1	0.0000	0000 0000
1	2.8125	0000 0001
1	5.6250	0000 0010
1	11.2500	0000 0100
1	22.5000	0000 1000
1	45.0000	0001 0000
1	90.0000	0010 0000
1	180.0000	0100 0000
1	357.1875	0111 1111

Step 2: Heading Data Not Available (§2.2.8.1.11.b)

Keep the Heading presence bit at "ONE," and set the Heading validity flag to "ZERO." Verify that the reported Binary Decoded Heading datum is set to all "ZEROs."

2.4.8.1.12 Verification of Altitude, Barometric (Pressure Altitude) Reporting (§2.2.8.1.12)

Purpose/Introduction:

These test procedures verify the proper reporting of Barometric Altitude as specified in §2.2.8.1.12.

Measurement Procedure:

Step 1: Barometric (Pressure) Altitude Reporting (§2.2.8.1.12.a)

For each case in Table 2-184 below, generate valid Airborne Position Messages, with "Type" codes of 9 through 18, which include the encoded datum ("ME" Bits 9 - 20) for the Decimal Altitude value listed, with an imbedded "Q" bit ("ME" Bit 16) of "ONE," and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Barometric (Pressure) Altitude presence bit (Report Byte #1, Bit #3), and the Barometric (Pressure) Altitude Validity Flag (Report Byte #3, Bit #2), are "ONEs."

Verify that the reported Binary Decoded Barometric (Pressure) Altitude datum (Report Bytes # 26 - 28) matches the corresponding value in the table.

Table 2-184: Barometric (Pressure) Altitude Test Data (Q Bit = 1)

Barometric (Pressure) Altitude ("Q" Bit = "1")	
Decimal Altitude (feet)	**Binary Decoded Barometric (Pressure) Altitude**
-1000	1111 1111 1110 0000 1100 0000
-975	1111 1111 1110 0001 1000 1000
-925	1111 1111 1110 0011 0001 1000
-825	1111 1111 1110 0110 0011 1000
-625	1111 1111 1110 1100 0111 1000
-575	1111 1111 1110 1110 0000 1000
-500	1111 1111 1111 0000 0110 0000
-225	1111 1111 1111 1000 1111 1000
-200	1111 1111 1111 1001 1100 0000
-125	1111 1111 1111 1100 0001 1000
-25	1111 1111 1111 1111 0011 1000
0	0000 0000 0000 0000 0000 0000
25	0000 0000 0000 0000 1100 1000
50	0000 0000 0000 0001 1001 0000
100	0000 0000 0000 0011 0010 0000
200	0000 0000 0000 0110 0100 0000
400	0000 0000 0000 1100 1000 0000
800	0000 0000 0001 1001 0000 0000
1600	0000 0000 0011 0010 0000 0000
3200	0000 0000 0110 0100 0000 0000
6400	0000 0000 1100 1000 0000 0000
12800	0000 0001 1001 0000 0000 0000
25600	0000 0011 0010 0000 0000 0000
49175	0000 0110 0000 0000 1011 1000
49200	0000 0110 0000 0001 1000 0000
50175	0000 0110 0001 1111 1111 1000

Step 2: Barometric (Pressure) Altitude Reporting (§2.2.8.1.12.a)

For each case in Table 2-185 below, generate valid Airborne Position Messages, with "Type" codes of 9 through 18, which include the encoded datum ("ME" Bits 9 - 20) for the Decimal Altitude value listed, with an imbedded "Q" bit ("ME" Bit 16) of "ZERO," and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Barometric (Pressure) Altitude presence bit (Report Byte #1, Bit 3), and the Barometric (Pressure) Altitude Validity Flag (Report Byte #3, Bit 2), are "ONEs."

Verify that the reported Binary Decoded Barometric (Pressure) Altitude datum (Report Bytes # 26 - 28) matches the corresponding value in the table.

Table 2-185: Barometric (Pressure) Altitude Test Data (Q Bit = 0)

Barometric (Pressure) Altitude ("Q" Bit = "0")	
Decimal Altitude (feet)	**Binary Decoded Barometric (Pressure) Altitude**
-1000	1111 1111 1110 0000 1100 0000
-800	1111 1111 1110 0111 0000 0000
-100	1111 1111 1111 1100 1110 0000
0	0000 0000 0000 0000 0000 0000
100	0000 0000 0000 0011 0010 0000
200	0000 0000 0000 0110 0100 0000
400	0000 0000 0000 1100 1000 0000
800	0000 0000 0001 1001 0000 0000
1600	0000 0000 0011 0010 0000 0000
3200	0000 0000 0110 0100 0000 0000
6400	0000 0000 1100 1000 0000 0000
12800	0000 0001 1001 0000 0000 0000
25600	0000 0011 0010 0000 0000 0000
51200	0000 0110 0100 0000 0000 0000
102400	0000 1100 1000 0000 0000 0000
126700	0000 1111 0111 0111 0110 0000

Step 3: Barometric (Pressure) Altitude Data Not Available (§2.2.8.1.12.b)

Keep the Barometric (Pressure) Altitude presence bit at "ONE," and set the Barometric (Pressure) Altitude validity flag to "ZERO." Verify that the reported Binary Decoded Barometric (Pressure) Altitude datum is set to all "ZEROs."

2.4.8.1.13 Verification of Vertical Rate, Geometric/Barometric (§2.2.8.1.13)

Purpose/Introduction:

The "Vertical Rate" field in the State Vector Report contains the altitude rate of an airborne ADS-B Participant. This is either the rate of change of pressure altitude, or of geometric altitude, as specified by the "Vertical Rate Type" element in the Mode Status Report (§2.2.8.2).

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to ONE (binary 0001) to indicate State Vector Report.

Step 2: Verification of Geometric Source for Vertical Rate

Input an ADS-B Airborne Velocity Message (Subtype 1) where the Vertical Rate is from a Geometric Source. Verify that the Vertical Rate Source Bit (ME Bit 36) is set to ZERO (0).

Step 3: Verification of Barometric Source for Vertical Rate

Input an ADS-B Airborne Velocity Message (Subtype 1) where the Vertical Rate is from a Barometric Source. Verify that the Vertical Rate Source Bit (ME Bit 36) is set to ONE (1).

Step 4: Verification of Vertical Rate – Data Not Available

Keep the Vertical Rate Presence bit at ONE (1), and set the Vertical Rate Validity Flag to ZERO (0). Verify that the reported Vertical Rate data is set to ALL ZEROs.

2.4.8.1.14 Verification of Vertical Rate, Geometric (WGS-84) Reporting (§2.2.8.1.14)

Purpose/Introduction:

These test procedures verify the proper reporting of Vertical Rate as specified in §2.2.8.1.14.

Measurement Procedure:

Step 1: Vertical Rate, Geometric (WGS-84) Reporting (§2.2.8.1.14.a)

For each case in Table 2-186 below, generate valid Airborne Velocity Messages (Subtype 1) with the Vertical Rate Source ("ME" Bit 36) equal "ZERO" (GNSS or INS Source), and which include the encoded data ("ME" Bit 37 for "Sign Bit for Vertical Rate," and Bits 38 - 46 for "Vertical Rate") for the Decimal Vertical Rate values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Geometric Vertical Rate presence bit (Report Byte #1, Bit #2), and the Geometric Vertical Rate Validity Flag (Report Byte #3, Bit #1), are “ONEs.”

Verify that the reported Binary Decoded Geometric (WGS-84) Vertical Rate datum (Report Bytes # 24 - 25) matches the corresponding value in the table.

Table 2-186: Geometric (WGS-84) Vertical Rate Test Data

Geometric (WGS-84) Vertical Rate	
Decimal Vertical Rate (ft./min.)	**Binary Decoded Geometric Vertical Rate**
-32704	1111 1000 0000 0100
-16384	1111 1100 0000 0000
-8192	1111 1110 0000 0000
-4096	1111 1111 0000 0000
-2048	1111 1111 1000 0000
-1024	1111 1111 1100 0000
-512	1111 1111 1110 0000
-256	1111 1111 1111 0000
-128	1111 1111 1111 1000
-64	1111 1111 1111 1100
0	0000 0000 0000 0000
64	0000 0000 0000 0100
128	0000 0000 0000 1000
256	0000 0000 0001 0000
512	0000 0000 0010 0000
1024	0000 0000 0100 0000
2048	0000 0000 1000 0000
4096	0000 0001 0000 0000
8192	0000 0010 0000 0000
16384	0000 0100 0000 0000
32704	0000 0111 1111 1100

Step 2: Vertical Rate, Geometric (WGS-84) Data Not Available (§2.2.8.1.14.b)

Keep the Geometric Vertical Rate presence bit at “ONE,” and set the Geometric Vertical Rate Validity Flag to “ZERO.” Verify that the reported Binary Decoded Geometric (WGS-84) Vertical Rate datum is set to “ALL ZEROs.”

2.4.8.1.15 Verification of Barometric Altitude Rate Reporting (§2.2.8.1.15)

Purpose/Introduction:

These test procedures verify the proper reporting of Barometric Altitude Rate as specified in §2.2.8.1.15.

Measurement Procedure:

Step 1: Vertical Rate Reporting (§2.2.8.1.15.a)

For each case in Table 2-187 below, generate valid Airborne Velocity Messages (Subtype 1) with the Vertical Rate Source ("ME" Bit 36) equal "ONE" (Barometric Source), and which include the encoded data ("ME" Bit 37 for "Sign Bit for Vertical Rate," and Bits 38 - 46 for "Vertical Rate") for the Decimal Vertical Rate values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Vertical Rate presence bit (Report Byte #1, Bit #2), and the Vertical Rate Validity Flag (Report Byte #3, Bit #0), are "ONEs."

Verify that the reported Binary Decoded Vertical Rate datum (Report Bytes # 29 - 30) matches the corresponding value in the table.

Table 2-187: Vertical Rate Test Data

Vertical Rate	
Decimal Vertical Rate (ft./min.)	**Binary Decoded Vertical Rate**
-32704	1111 1000 0000 0100
-16384	1111 1100 0000 0000
-8192	1111 1110 0000 0000
-4096	1111 1111 0000 0000
-2048	1111 1111 1000 0000
-1024	1111 1111 1100 0000
-512	1111 1111 1110 0000
-256	1111 1111 1111 0000
-128	1111 1111 1111 1000
-64	1111 1111 1111 1100
0	0000 0000 0000 0000
64	0000 0000 0000 0100
128	0000 0000 0000 1000
256	0000 0000 0001 0000
512	0000 0000 0010 0000
1024	0000 0000 0100 0000
2048	0000 0000 1000 0000
4096	0000 0001 0000 0000
8192	0000 0010 0000 0000
16384	0000 0100 0000 0000
32704	0000 0111 1111 1100

Step 2: Vertical Rate Data Not Available (§2.2.8.1.15.b)

Keep the Vertical Rate presence bit at "ONE," and set the Vertical Rate Validity Flag to "ZERO." Verify that the reported Binary Decoded Vertical Rate datum is set to "ALL ZEROs."

2.4.8.1.16 Verification of the Navigation Integrity Code (NIC) (§2.2.8.1.16)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function extracts "TYPE" Code data (§2.2.3.2.3.1) and the NIC Supplement value (§2.2.3.2.3.3) from the ADS-B Airborne Position Message, or the "TYPE" Code data (§2.2.3.2.4.1) from the ADS-B Surface Position Message, and the NIC Supplement value (§2.2.3.2.7.2.6) from the ADS-B Aircraft Operational Status Message, and provides Navigation Integrity Category (NIC) information to the user application in the State Vector Report as specified in Table 2-81. Definition of the NIC coding is provided in Table 2-70.

Measurement Procedure:

Step 1: Verification of (NIC) on Receipt of ADS-B Messages – Version Zero (0)

Set up to simulate reception of Version Zero (0) ADS-B Messages by inputting data directly to the ADS-B Receiving Subsystem. Table 2-188 shows how a Version One or above ADS-B Receiving Subsystem **shall** interpret the NUC_P Codes that it receives from a Version Zero ADS-B Transmitting Subsystem. Using Table 2-188 input the TYPE Code values found in each row of the table and verify that the corresponding NIC value in that row is reflected in the next output State Vector Report. Repeat this procedure for each row in the table.

Table 2-188: Interpretation of NUC_P Codes from Version Zero Transmitting Subsystems When Received by Version One or above ADS-B Receiving Subsystems

Values Sent By Version Zero Transmitting Subsystem		Values Inferred by Version One or Above Receiving Subsystem			Notes
Message TYPE Codes	NUC_P	NAC (§2.2.3.2.7.2.7)	NIC (§2.2.3.2.7.2.6)	SIL (§2.2.3.2.7.2.9)	
0	0	0 (HFOM ≥ 10 NM)	0 (R_C ≥ 20 NM)	0 (No Integrity)	
5	9	11 (HFOM < 3 m)	11 (R_C < 7.5 m)	2 ("5 nines")	
6	8	10 (HFOM < 10 m)	10 (R_C < 25 m)	2 ("5 nines")	
7	7	8 (HFOM < 0.05 NM)	8 (R_C < 0.1 NM)	2 ("5 nines")	
8	6	0 (HFOM ≥ 0.05 NM)	0 (R_C ≥ 0.1 NM)	0 (No Integrity)	[1]
9	9	11 (HFOM < 3 m)	11 (R_C < 7.5 m)	2 ("5 nines")	
10	8	10 (HFOM < 10 m)	10 (R_C < 25 m)	2 ("5 nines")	
11	7	8 (HFOM < 0.05 NM)	8 (R_C < 0.1 NM)	2 ("5 nines")	
12	6	7 (HFOM < 0.1 NM)	7 (R_C < 0.2 NM)	2 ("5 nines")	
13	5	6 (HFOM < 0.3 NM)	6 (R_C < 0.5 NM)	2 ("5 nines")	
14	4	5 (HFOM < 0.5 NM)	5 (R_C < 1.0 NM)	2 ("5 nines")	
15	3	4 (HFOM < 1.0 NM)	4 (R_C < 2.0 NM)	2 ("5 nines")	
16	2	1 (HFOM < 10.0 NM)	1 (R_C < 8 NM)	2 ("5 nines")	
17	1	1 (HFOM < 10 NM)	1 (R_C < 20 NM)	2 ("5 nines")	
18	0	0 (HFOM ≥ 10 NM)	0 (R_C ≥ 20 NM)	0 (No Integrity)	
20	9	11 (HFOM < 3 m, VFOM < 4 m)	11 (R_C < 7.5 m)	2 ("5 nines")	[2]
21	8	10 (HFOM < 10 m, VFOM < 15 m)	10 (R_C < 25 m)	2 ("5 nines")	[2]
22	TBD	0 (HFOM ≥ 10 NM or unknown)	0 (R_C ≥ 25 m or unknown)	0 (No Integrity)	[2]

Table 2-189 shows how a Version Zero ADS-B Receiving Subsystem would interpret the NIC Codes that it receives from a Version One or above ADS-B Transmitting Subsystem.

Table 2-189: Interpretation of NIC Codes from Version One or Above Transmitting Subsystems When Received by Version Zero Receiving Subsystems

TYPE Code in Message From Version One Transmitting Subsystem	NIC Value from Version One or Above Transmitting Subsystem	NUC_P Value Assumed by Version Zero Receiving Subsystem	Notes
0	0 (R_C unknown or $\geq$ 20 NM)	0 (HPL $\geq$ NM or HFOM $\geq$ 10 NM)	
5	11 (R_C < 7.5 m)	9 (HPL < 7.5 m or HFOM < 3 m)	
6	10 (R_C < 25 m)	8 (HPL < 25 m or HFOM < 10 m)	
7	8 (R_C < 0.1 NM)	7 (HPL < 0.1 NM or HFOM < 0.05 NM)	
8	0 (R_C $\geq$ 0.1 NM)	6 (HPL $\geq$ 0.1 NM or HFOM $\geq$ 0.05 NM)	[1]
9	11 (R_C < 7.5 m)	9 (HPL < 7.5 m or HFOM < 3 m)	
10	10 (R_C < 25 m)	8 (HPL < 25 m or HFOM < 10 m)	
11	8 (R_C < 0.1 NM)	7 (HPL < 0.1 NM or HFOM < 0.05 NM)	
12	7 (R_C < 0.2 NM)	6 (HPL < 0.05 NM or HFOM < 0.1 NM)	
13	6 (R_C < 0.5 NM)	5 (HPL < 0.5 NM or HFOM < 0.25 NM)	[3]
14	5 (R_C < 1.0 NM)	4 (HPL < 1.0 NM or HFOM < 0.5 NM)	
15	4 (R_C < 2 NM)	3 (HPL < 2 NM or HFOM < 1.0 NM)	
16	2 (R_C < 8 NM)	2 (HPL < 10 NM or HFOM < 5.0 NM)	
17	1 (R_C < 20 NM)	1 (HPL < 20 NM or HFOM < 10 NM)	
18	0 (R_C $\geq$ 20 NM)	0 (HPL $\geq$ 20 NM or HFOM $\geq$ 10 NM)	
20	11 (R_C < 7.5 m)	0 (HPL and HFOM are unknown)	[2]
21	10 (R_C < 25 m)	0 (HPL and HFOM are unknown)	[2]
22	0 (R_C $\geq$ 25 m or unknown)	0 (HPL and HFOM are unknown)	[2]

Notes for Table 2-188 and Table 2-189:

1. *In Table 2-11 of the initial version (RTCA DO-260) of these MOPS (also see Table 2-16 in this document), a NUC_P value of 6 was assigned to Surface Position Messages with a TYPE Code of 8. This coding is preserved in Table 2-189 because that table shows how equipment that conforms to the initial RTCA DO-260 MOPS will interpret this message TYPE Code. However, Table 2-188 specifies that Surface Position Messages with a TYPE Code of 8 should be interpreted by Version Two (i.e., RTCA DO-260B compliant) Receiving Subsystems as specifying that NIC, NAC and SIL should all be ZERO (0). This is because the information in the message is insufficient to indicate the value of either the R_C Integrity Containment Radius, or the HFOM 95% Horizontal Accuracy Bound.*
2. *In the initial version of these MOPS (RTCA DO-260), message TYPE Codes of 20 through 22 were determined primarily by the HPL Containment Radius and secondarily, if the HPL value was unknown, by the 95% Horizontal and Vertical Accuracy Bounds. However, the initial version of the ADS-B MASPS (RTCA DO-242) required that NUC_P Codes of 8 and 9 should be determined by only the 95% Horizontal and Vertical Accuracy Bounds. Therefore, a Version Zero 1090 MHz ADS-B Receiving Subsystem cannot reliably assign a NUC_P Code based on Airborne Position Messages of Message TYPE Codes of 20 through 22 from Version One ADS-B Transmitting Subsystems. It is for that reason that Table 2-189 specifies that Message TYPE Codes of 20 through 22 from Version One and Two Transmitting Subsystems should be interpreted by Version Zero ADS-B Receiving Susbsystems as conveying a NUC_P Code of ZERO (0), meaning that there is "No Integrity" or "unknown integrity."*
3. *A Version One or Two ADS-B Transmitting Subsystem will set the TYPE Code in the Airborne Position Message to 13 whenever the HFOM is less than 0.3 NM, but a Version Zero ADS-B Receiving Susbsystem will assume that TYPE Code of 13 means that HFOM is less than 0.25 NM, rather than 0.3 NM.* ***It is assumed that there are no client applications that would demand HFOM = 0.25 NM rather than HFOM = 0.3 NM.***

Step 2: Verification of (NIC) on Receipt of ADS-B Messages – Version One (1)

Set up to simulate Version One (1) ADS-B Messages by inputting data directly to the ADS-B Receiving Subsystem being sure to first input an Aircraft Operational Status Message indicating Version One. Using Table 2-70 input the TYPE Code and NIC Supplement values found in each row of the table and verify that the corresponding NIC value is reflected in the next output State Vector Report. Repeat this procedure for each row in Table 2-70 for both Airborne and Surface Position Messages.

Step 3: Verification of (NIC) on Receipt of ADS-B Messages ̃ Version Two (2)

Set up to simulate Version Two (2) ADS-B Messages by inputting data directly to the ADS-B Receiving Subsystem being sure to first input an Aircraft Operational Status Message indicating Version Two. Using Table 2-70 input the TYPE Code and NIC Supplement values found in each row of the table and verify that the corresponding NIC value is reflected in the next output State Vector Report. Repeat this procedure for each row in Table 2-70 for both Airborne and Surface Position Messages.

2.4.8.1.17 Verification of Estimated Latitude (WGS-84) Reporting (§2.2.8.1.17)

Purpose/Introduction:

These test procedures verify the proper reporting of Estimated Latitude as specified in §2.2.8.1.17.

Measurement Procedure:

Step 1: Estimated Latitude (WGS-84) Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.17.a(1))

For each case in Table 2-191 below, generate valid Airborne Position Messages, which include the encoded data ("ME" Bits 23 - 39) for the Decimal Latitude value listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Estimated Latitude presence bit (Report Byte #1, Bit 0), and the Estimated Latitude Validity Flag (Report Byte #4, Bit 7), are "ONEs."

Verify that the reported Binary Decoded Estimated Latitude (WGS-84) (Report Bytes # 44 - 46) data, match the corresponding value in the table.

Table 2-190: Estimated Longitude Test Data

Estimated Longitude	
Decimal Longitude (degrees)	**Binary Decoded (WGS-84) Estimated Longitude (angular weighted)**
0.000000	0000 0000 0000 0000 0000 0000
0.000037	0000 0000 0000 0000 0000 0001
0.000073	0000 0000 0000 0000 0000 0011
0.000147	0000 0000 0000 0000 0000 0110
0.000294	0000 0000 0000 0000 0000 1101
0.000587	0000 0000 0000 0000 0001 1011
0.001175	0000 0000 0000 0000 0011 0110
0.002350	0000 0000 0000 0000 0110 1101
0.004699	0000 0000 0000 0000 1101 1011
0.009398	0000 0000 0000 0001 1011 0110
0.018797	0000 0000 0000 0011 0110 1100
0.037594	0000 0000 0000 0110 1101 1000
0.075188	0000 0000 0000 1101 1011 0000
0.150375	0000 0000 0001 1011 0110 0000
0.300751	0000 0000 0011 0110 1100 0000
0.601501	0000 0000 0110 1101 1000 0000
1.203003	0000 0000 1101 1011 0000 0000
2.406006	0000 0001 1011 0110 0000 0000
4.812012	0000 0011 0110 1100 0000 0000
9.624023	0000 0110 1101 1000 0000 0000
19.248047	0000 1101 1011 0000 0000 0000
38.496094	0001 1011 0110 0000 0000 0000
76.992188	0011 0110 1100 0000 0000 0000
153.984375	0110 1101 1000 0000 0000 0000
-52.031250	1101 1011 0000 0000 0000 0000
-104.062500	1011 0110 0000 0000 0000 0000
151.875000	0110 1100 0000 0000 0000 0000
-56.250000	1101 1000 0000 0000 0000 0000
-112.500000	1011 0000 0000 0000 0000 0000
135.000000	0110 0000 0000 0000 0000 0000
-90.000000	1100 0000 0000 0000 0000 0000
180.000000	1000 0000 0000 0000 0000 0000

Step 2: Estimated Latitude and Estimated Longitude (WGS-84) Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.18.a(1))

For each case in Table 2-190 above, generate valid Airborne Position Messages, which include the encoded data ("ME" Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for the Decimal Latitude and Longitude values listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Estimated Latitude and Longitude presence bits (Report Byte #1, Bit #0 for Estimated Latitude, and Byte #2, Bit #7 for Estimated Longitude), and the Estimated Latitude / Longitude Validity Fag (Report Byte #4, Bit #7), are "ONEs."

Verify that the reported Binary Decoded Estimated Latitude (WGS-84) (Report Bytes # 44 - 46) data, and the reported Binary Decoded Estimated Longitude (WGS-84) (Report Bytes # 47 - 49) data, match the corresponding values in the table.

Table 2-191: Estimated Latitude Test Data

Estimated Latitude	
Decimal Latitude (degrees)	**Binary Decoded (WGS-84) Estimated Latitude (angular weighted)**
0.000000	0000 0000 0000 0000 0000 0000
0.000037	0000 0000 0000 0000 0000 0001
0.000073	0000 0000 0000 0000 0000 0011
0.000147	0000 0000 0000 0000 0000 0110
0.000294	0000 0000 0000 0000 0000 1101
0.000587	0000 0000 0000 0000 0001 1011
0.001175	0000 0000 0000 0000 0011 0110
0.002350	0000 0000 0000 0000 0110 1101
0.004699	0000 0000 0000 0000 1101 1011
0.009398	0000 0000 0000 0001 1011 0110
0.018797	0000 0000 0000 0011 0110 1100
0.037594	0000 0000 0000 0110 1101 1000
0.075188	0000 0000 0000 1101 1011 0000
0.150375	0000 0000 0001 1011 0110 0000
0.300751	0000 0000 0011 0110 1100 0000
0.601501	0000 0000 0110 1101 1000 0000
1.203003	0000 0000 1101 1011 0000 0000
2.406006	0000 0001 1011 0110 0000 0000
4.812012	0000 0011 0110 1100 0000 0000
9.624023	0000 0110 1101 1000 0000 0000
19.248047	0000 1101 1011 0000 0000 0000
38.496094	0001 1011 0110 0000 0000 0000
76.992188	0011 0110 1100 0000 0000 0000
-52.031250	1101 1011 0000 0000 0000 0000
-56.250000	1101 1000 0000 0000 0000 0000
-90.000000	1100 0000 0000 0000 0000 0000

Step 3: Report Time of Applicability Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.17.a(2), and §2.2.8.1.18.a(2))

Generate a series of valid Airborne Position Messages, similar to the procedure described in Step 1 above, which include the encoded data ("ME" Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for any suitable Decimal Latitude and Longitude values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding presence bits (Report Byte #1, Bit #0 for Estimated Latitude, and Byte #2, Bit #7 for Estimated Longitude), and the Estimated Latitude/Longitude Validity Flag (Report Byte #4, Bit #7), are "ONEs."

Verify that the Binary Decoded Report Time of Applicability (Report Bytes # 55 - 56) data changes by an average of 0.5 seconds between each message transmission.

Step 4: Estimated Latitude and Estimated Longitude (WGS-84) Updating and Reporting (resulting from received Airborne Velocity Message - Subtype=1) (§2.2.8.1.17.b(1 & 2), and §2.2.8.1.18.b(1 & 2))

Generate an Airborne Velocity Message (Subtype 1), which includes the encoded data ("ME" Bits 25 - 35) for any suitable N/S Velocity, and which includes the encoded data ("ME" Bits 14 - 24) for any suitable E/W Velocity, such that the resultant is a velocity of 180 knots, and a heading of between 25 to 65 degrees. Verify that the ADS-B Receiver/Report Assembly outputs a State Vector Report with the Report Mode set to TWO (binary xxxx 0010). Record the Estimated N/S Velocity (Report Bytes # 50 - 51) as Vns_{est0} (knots), and record the Estimated E/W Velocity (Report Bytes # 50 - 51) as Vew_{est0} (knots).

Within 200 milliseconds, generate any valid Airborne Position Message, which includes the encoded data ("ME" Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for any suitable Decimal Latitude and Longitude values. Verify that the ADS-B Receiver/Report Assembly outputs a State Vector Report with the Report Mode set to TWO (binary xxxx 0010). Record the Position Time of Applicability (Report Bytes # 40 - 41) as t_0 (seconds), record the Estimated Latitude (Report Bytes # 44 - 46) as Lat_{est0} (degrees), and record the Estimated Longitude (Report Bytes # 47 - 49) as Lon_{est0} (degrees).

One second after the Airborne Position Message, retransmit the same Airborne Velocity Message (Subtype 1) as above. Verify that the ADS-B Receiver/Report Assembly outputs State Vector Report with the Report Mode set to TWO (binary xxxx 0010). Record the updated Estimated Latitude as Lat_{est1} (degrees). Record the updated Estimated Longitude as Lon_{est1} (degrees), and record the updated Velocity Time of Applicability as t_1 (seconds).

Verify that (see Note below):

$$1852 * \text{Absolute}\,[(Lat_{est1} - Lat_{est0}) \times 60 - Vns_{est0} \times (t_1 - t_0 + t_{rng}) / 3600] < 20 \text{ meters.}$$

Verify that (see Note below):

$$1852 * \text{Absolute}\,[(Lon_{est1} - Lon_{est0}) \times 60 - Vew_{est0} \times (t_1 - t_0 + t_{rng}) / 3600] < 20 \text{ meters.}$$

Note: *If $t_1 < t_0$, then the Receiving Installation Time has exceeded the maximum time range (see §2.2.8.5) to restart the time count at zero, then the maximum time range, t_{rng} , must be added to $(t_1 - t_0)$ to make it positive. Otherwise, consider t_{rng} in the equation to be zero.*

Repeat these Step 3 procedures as necessary, using various parameter values, in order to establish the desired level of confidence.

Step 5: Estimation of Latitude and Longitude when Receiving Air Referenced Velocity

This step verifies that Estimated Latitude and Longitude properly updates on receipt of ground referenced velocity and does not update on receipt of air referenced velocity (Airborne Velocity Messages, Subtypes 3 or 4).

Repeat Step 4 above with the additional input of Airborne Velocity Messages (Subtype 3). Input an Airspeed of 1000 knots at the nominal broadcast rate of 2 messages per second. Verify that the ADS-B Receiving Subsystem and Report Assembly Function outputs a State Vector Report that meets the ±20 meter position accuracy required in Step 4.

Step 6: Report Time of Applicability Updating and Reporting (resulting from received Airborne Velocity Message - Subtype=1) (§2.2.8.1.17.b(3), and §2.2.8.1.18.b(3))

Generate a series of valid Airborne Velocity Messages (Subtype 1), similar to the procedure described in Step 3 above, which include the encoded data ("ME" Bits 25 - 35 for N/S Velocity, and "ME" Bits 14 - 24 for E/W Velocity) for any suitable N/S and E/W Velocity values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding N/S Velocity presence bit (Report Byte #1, Bit 6), and the Velocity Validity Flag (Report Byte #3, Bit #5), are "ONEs."

Verify that the Binary Decoded Report Time of Applicability (Report Bytes # 55 - 56) data changes by an average of 0.5 seconds between each message transmission.

Step 7: Estimated Latitude and Estimated Longitude (WGS-84) Data Not Available (§2.2.8.1.17.c, and §2.2.8.1.18.c)

Keep the Estimated Latitude and Longitude presence bits at "ONE," and set the Estimated Latitude / Longitude Validity Flag to "ZERO."

Verify that the reported Binary Decoded Estimated Latitude and Estimated Longitude data are set to all "ZEROs."

2.4.8.1.18 Verification of Estimated Longitude (WGS-84) Reporting (§2.2.8.1.18)

Appropriate test procedures are provided in §2.4.8.1.17.

2.4.8.1.19 Verification of Estimated North/South Velocity Reporting (§2.2.8.1.19)

Purpose/Introduction:

These test procedures verify the proper reporting of Estimated North/South Velocity as specified in §2.2.8.1.19.

Measurement Procedure:

Step 1: Estimated North/South Velocity Updating and Reporting (resulting from received Airborne Velocity Message) (§2.2.8.1.19.a(1))

Generate valid Airborne Velocity Messages (Subtype 1), which include the encoded data ("ME" Bits 25 - 35) for any valid Decimal North/South Velocity values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Estimated North/South Velocity presence bit (Report Byte #2, Bit #6), and the Estimated Velocity Validity Flag (Report Byte #4, Bit #6), are "ONEs."

Verify that the reported Binary Decoded Estimated North/South Velocity data (Report Bytes # 50 - 51) match the transmitted North/South Velocity values.

Step 2: Estimated North/South Velocity Updating and Reporting (resulting from received Surface Position Message) (§2.2.8.1.19.a(1))

Generate a series of Surface Position Messages (Subtype 1 or 2), which include encoded data ("ME" Bits 6 - 12) for valid Ground Speed (Movement) values, which include a Ground Track Status ("ME" Bit 13) of "ONE," and which include encoded data ("ME" Bits 14 - 20) for valid Ground Track headings having a significant North/South component, and verify that the ADS-B Receiver/Report Assembly outputs a State Vector Report of Type 0001.

Verify that the North/South Velocity presence bit (Report Byte #1, Bit #6), the Estimated North/South Velocity presence bit (Report Byte #2, Bit #6), the Velocity Validity Flag (Report Byte #3, Bit #5), and the Estimated Velocity Validity Flag (Report Byte #4, Bit #6), are "ONEs."

Verify that for each message the N/S Velocity (Report Bytes # 20 - 21) data matches the Estimated N/S Velocity (Report Bytes # 50 - 51) data.

Step 3: Report Time of Applicability Updating and Reporting (resulting from received Airborne Velocity or Surface Position Message) (§2.2.8.1.19.a(2))

Generate a series of valid Airborne Velocity Messages (Subtype 1), which include the encoded data ("ME" Bits 25 - 35) for any suitable N/S Velocity values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Estimated North/South Velocity presence bit (Report Byte #2, Bit #6), and the Estimated Velocity Validity Flag (Report Byte #4, Bit #6), are “ONEs.”

Verify that the Binary Decoded Report Time of Applicability (Report Bytes # 55 - 56) data changes by an average of 0.5 seconds between each message transmission.

Step 4: Estimated North/South Velocity Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.19.b(1 & 2))

Generate any valid Surface Position Message, which includes the encoded data (“ME” Bits 6 - 12) for a suitable Decimal Ground Speed (Movement) value, which includes the encoded data (“ME” Bits 14 - 20) for a suitable Decimal Ground Track value, representing a North/South movement and speed of about 25 meters in a three second period, and which includes the encoded data (“ME” Bits 23 - 39) for any suitable starting Decimal Latitude value. Verify that the ADS-B Receiver/Report Assembly outputs a State Vector Report of Type 0001. Record the Position Time of Applicability (Report Bytes # 40 - 41) as t_{Y0} (seconds). Record the Velocity Time of Applicability (Report Bytes # 42 - 43) as t_{V0} (seconds). Record the Estimated Latitude (Report Bytes # 44 - 46) as Lat_{est0} (degrees). Record the Estimated N/S Velocity (Report Bytes # 50 - 51) as Vns_{est0} (knots), and record the Report Time of Applicability (Report Bytes # 55 - 56) as t_{R0} (seconds).

Three seconds after the first Surface Position Message, generate another valid Surface Position Message, which includes the same encoded data for Decimal Ground Speed (Movement), the same encoded data for Decimal Ground Track, and updated encoded data for a Decimal Latitude value commensurate with the previously recorded Latitude, the N/S Velocity (Vns_{est0}), and the time between updates of the two Surface Position Messages (t_{Y1} - t_{Y0}). Verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001. Record the Position Time of Applicability as t_{Y1} (seconds). Record the Estimated Latitude as Lat_{est1} (degrees), and record the Report Time of Applicability as t_{R1} (seconds).

Verify that $t_{Y0} = t_{V0}. = t_{R0}$.

Verify that $t_{Y1} = t_{V1}. = t_{R1}$.

Verify that:

$$1852 \text{ x Absolute } [(Lat_{est1} - Lat_{est0}) \text{ x } 60 / (t_{Y1} - t_{Y0} + t_{rng}) - Vns_{est0} / 3600] < 0.3 \text{ meters/second}$$

Note: *If $t_{Y1} < t_{Y0}$, then the Receiving Installation Time has exceeded the maximum time range (see §2.2.8.5) to restart the time count at zero, then the maximum time range, t_{rng} , must be added to (t_{Y1} - t_{Y0}) to make it positive. Otherwise, consider t_{rng} in the equation to be zero.*

Repeat these Step 4 procedures as necessary, using various parameter values, in order to establish the desired level of confidence.

Step 5: Report Time of Applicability Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.19.b(3))

Generate a series of valid Airborne Position Messages, which include the encoded data ("ME" Bits 23 - 39) for any suitable changing Latitude values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Latitude presence bit (Report Byte #0, Bit #0), and the Latitude/Longitude Validity Flag (Report Byte #3, Bit #7), are "ONEs."

Verify that the Binary Decoded Report Time of Applicability (Report Bytes # 55 - 56) data changes by an average of 0.5 seconds between each message transmission.

Step 6: North/South Velocity Data Not Available (§2.2.8.1.19.c)

Generate a series of valid Airborne Velocity Messages, which include the encoded data ("ME" Bits 25 - 35) for any suitable N/S Velocity values, force an "Estimated N/S Velocity data not available" condition in the ADS-B Receiver, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the N/S Velocity presence bit (Report Byte #1, Bit #6), and the Estimated N/S Velocity presence bit (Report Byte #2, Bit #6), are "ONEs," and that the reported Estimated Velocity Validity Flag (Report Byte #4, Bit 6) is a "ZERO."

Verify that the reported Binary Decoded Estimated N/S Velocity data (Report Bytes # 50 - 51) is set to all "ZEROs."

2.4.8.1.20 Verification of Estimated East/West Velocity Reporting (§2.2.8.1.20)

Purpose/Introduction:

These test procedures verify the proper reporting of Estimated East/West Velocity as specified in §2.2.8.1.20.

Measurement Procedure:

Step 1: Estimated East/West Velocity Updating and Reporting (resulting from received Airborne Velocity Message) (§2.2.8.1.20.a(1))

Generate valid Airborne Velocity Messages (Subtype 1), which include the encoded data ("ME" Bits 14 - 24) for any valid Decimal East/West Velocity values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Estimated East/West Velocity presence bit (Report Byte #2, Bit #5), and the Estimated Velocity Validity Flag (Report Byte #4, Bit #7), are "ONEs."

Verify that the reported Binary Decoded Estimated East/West Velocity data (Report Bytes # 52 - 53) match the transmitted East/West Velocity values.

Step 2: Estimated East/West Velocity Updating and Reporting (resulting from received Surface Position Message) (§2.2.8.1.20.a(1))

Generate a series of Surface Position Messages (Subtype 1 or 2), which include encoded data ("ME" Bits 6 - 12) for valid Ground Speed (Movement) values, which include a Ground Track Status ("ME" Bit 13) of "ONE," and which include encoded data ("ME" Bits 14 - 20) for valid Ground Track headings having a significant East/West component, and verify that the ADS-B Receiver/Report Assembly outputs a State Vector Report of Type 0001.

Verify that the East/West Velocity presence bit (Report Byte #1, Bit #6), the Estimated East/West Velocity presence bit (Report Byte #2, Bit #5), the Velocity Validity Flag (Report Byte #3, Bit #5), and the Estimated Velocity Validity Flag (Report Byte #4, Bit #7), are "ONEs."

Verify that for each message the E/W Velocity (Report Bytes # 22 - 23) data matches the Estimated E/W Velocity (Report Bytes # 52 - 53) data.

Step 3: Report Time of Applicability Updating and Reporting (resulting from received Airborne Velocity Message or Surface Position Message) (§2.2.8.1.20.a(2))

Generate a series of valid Airborne Velocity Messages (Subtype 1), which include the encoded data ("ME" Bits 14 - 24) for any suitable E/W Velocity values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Estimated East/West Velocity presence bit (Report Byte #2, Bit #5), and the Estimated Velocity Validity Flag (Report Byte #4, Bit 7), are "ONEs."

Verify that the Binary Decoded Report Time of Applicability (Report Bytes # 55 - 56) data changes by an average of 0.5 seconds between each message transmission.

Step 4: Estimated East/West Velocity Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.20.b(1 & 2))

Generate any valid Surface Position Message, which includes the encoded data ("ME" Bits 6 - 12) for a suitable Decimal Ground Speed (Movement) value, and the encoded data ("ME" Bits 14 - 20) for a suitable Decimal Ground Track value, representing a East/West movement and speed of about 25 meters in a three second period, and which includes the encoded data ("ME" Bits 40 - 56) for any suitable starting Decimal Latitude (Lat) and Longitude values. Verify that the ADS-B Receiver/Report Assembly outputs a State Vector Report of Type 0001.

Record the Position Time of Applicability (Report Bytes # 40 - 41) as t_{X0} (seconds). Record the Velocity Time of Applicability (Report Bytes # 42 - 43) as t_{V0} (seconds). Record the Estimated Longitude (Report Bytes # 44 - 46) as Lon_{est0} (degrees). Record the Estimated E/W Velocity (Report Bytes # 52 - 53) as Vew_{est0} (knots), and record the Report Time of Applicability (Report Bytes # 55 - 56) as t_{R0} (seconds).

Three seconds after the first Surface Position Message, generate another valid Surface Position Message, which includes the same encoded data for Decimal Ground Speed (Movement), the same encoded data for Decimal Ground Track, and updated encoded data for a Decimal Longitude value commensurate with the previously recorded Longitude, the E/W Velocity (Vew_{est0}), and the time between updates of the two Surface Position Messages (t_{X1} - t_{X0}). Verify that the ADS-B Receiver/Report Assembly outputs State Vector Report of Type 0001. Record the Position Time of Applicability as t_{X1} (seconds). Record the Estimated Longitude as Lon_{est1} (degrees), and record the Report Time of Applicability as t_{R1} (seconds).

Verify that $t_{X0} = t_{V0}. = t_{R0}$.

Verify that $t_{X1} = t_{V1}. = t_{R1}$.

Verify that:

$$1852 \text{ x Absolute } [(Lon_{est1} - Lon_{est0}) \text{ x } 60 / (t_{X1} - t_{X0} + t_{rng}) - Vew_{est0} / 3600] \cos(Lat) < 0.3 \text{ meters/second.}$$

Note: *If $t_{X1} < t_{X0}$, then the Receiving Installation Time has exceeded the maximum time range (see §2.2.8.5) to restart the time count at zero, then the maximum time range, t_{rng} , must be added to (t_{X1} - t_{X0}) to make it positive. Otherwise, consider t_{rng} in the equation to be zero.*

Repeat these Step 4 procedures as necessary, using various parameter values, in order to establish the desired level of confidence.

Step 5: Report Time of Applicability Updating and Reporting (resulting from received Airborne or Surface Position Message) (§2.2.8.1.20.b(3))

Generate a series of valid Airborne Position Messages, which include the encoded data (“ME” Bits 40 - 56) for any suitable changing Longitude values, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Longitude presence bit (Report Byte #0, Bit #0), and the Latitude/Longitude Validity Flag (Report Byte #3, Bit 7), are “ONEs.”

Verify that the Binary Decoded Report Time of Applicability (Report Bytes # 55 - 56) data changes by an average of 0.5 seconds between each message transmission.

Step 6: East/West Velocity Data Not Available (§2.2.8.1.20.c)

Generate a series of valid Airborne Velocity Messages, which include the encoded data (“ME” Bits 14 - 24) for any suitable E/W Velocity values, force an “Estimated E/W Velocity data not available” condition in the ADS-B Receiver, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the E/W Velocity presence bit (Report Byte #1, Bit #6), and the Estimated E/W Velocity presence bit (Report Byte #2, Bit #5), are “ONEs,” and set the reported Estimated Velocity Validity Flag (Report Byte #4, Bit 7) is a “ZERO.”

Verify that the reported Binary Decoded Estimated E/W Velocity data (Report Bytes # 52 - 53) is set to all “ZEROs.”

2.4.8.1.21 Verification of Surveillance Status / Discretes Reporting (§2.2.8.1.21)

Purpose/Introduction:

These test procedures verify the proper reporting of Surveillance Status / Discretes as specified in §2.2.8.1.21.

Measurement Procedure:

Step 1: Surveillance Status Updating and Reporting (resulting from received Airborne Position Message) (§2.2.8.1.21.a)

For each case in Table 2-192 below, generate valid Airborne Position Messages, which includes encoded data (“ME” Bits 6 - 7) for the Surveillance Status Test Condition listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Surveillance Status / Discretes presence bit (Report Byte #3, Bit 3) is a “ONE.”

Verify that the reported Binary Decoded Surveillance Status / Discretes data (Report Byte # 54, Bits 5 & 4) match the corresponding bit values indicated in the table.

Table 2-192: Surveillance Status Test Conditions

Surveillance Status / Discretes	
Surveillance Status Test Conditions	**Binary Decoded Surveillance Status / Discretes**
No Condition Information	xx00 xxxx
Permanent Alert Condition (Emergency)	xx01 xxxx
Temporary Alert Condition (change in Mode-A Identity Code other than emergency condition)	xx10 xxxx
Special Position Identification (SPI) Condition	xx11 xxxx

Step 2: Surveillance Status Data Not Available (resulting from received Airborne Position Message) (§2.2.8.1.21.b)

Generate a series of valid Airborne Position Messages, force a "Surveillance Status data not available" condition in the ADS-B Receiver, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Surveillance Status / Discretes presence bit (Report Byte #3, Bit 3) is a "ONE."

Verify that the reported Binary Surveillance Status / Discretes data (Report Byte # 54, Bits 5 & 4) is set to all "ZEROs."

Step 3: Intent Change Flag Updating and Reporting (resulting from received Airborne Velocity Message) (§2.2.8.1.21.c)

For each case in Table 2-193 below, generate valid Airborne Velocity Messages (Subtype 1), which includes encoded data ("ME" Bit 9) for the Intent Change Flag Test Condition listed, and verify that the ADS-B Receiver/Report Assembly outputs State Vector Reports of Type 0001.

Verify that the corresponding Surveillance Status / Discretes presence bit (Report Byte #3, Bit 3) is a "ONE."

Verify that the reported Binary Decoded Surveillance Status / Discretes data (Report Byte # 54, Bit 1) matches the corresponding bit value indicated in the table.

Table 2-193: Intent Change Flag Test Conditions

Surveillance Status / Discretes	
Intent Change Flag Test Conditions	**Binary Decoded Surveillance Status / Discretes**
No Change in Intent	xxxx xx0x
Intent Change	xxxx xx1x

Step 4: Surveillance Status / Discrete Bit "b0" (§2.2.8.1.21.d)

Verify that the reported Binary Decoded Surveillance Status / Discretes datum (Report Byte # 54, Bit 0) is set to ZERO (0).

2.4.8.1.22 Verification of Report Mode Reporting (§2.2.8.1.22)

Purpose/Introduction:

The Report Mode is used to indicate the current state of the Report for each ADS-B vehicle being reported. Each time that the State Vector Report is updated, the Report Mode is updated with the encoding being as shown in Table 2-195:

Table 2-195: Report Mode Encoding

Coding	Report Mode
xxxx 0000	No Report Generation Capability
xxxx 0001	Acquisition Mode (see §2.2.10.2)
xxxx 0010	Track Mode (see §2.2.10.3)
xxxx 0011 through xxxx 1111	Reserved for Future Expansion

Note: *"x" in the table above, denotes "DON'T CARE."*

Measurement Procedure:

Step 1: Acquisition Mode Reporting (§2.2.8.1.22, §2.2.10.2)

Generate two valid Airborne Position Messages within 10 seconds, one **"even"** and one **"odd."**

Verify that the reported Binary Report Mode field (Report Byte #57) is set to "xxxx 0001."

Step 2: Track State Initialization Mode Reporting (§2.2.8.1.22, §2.2.10.3)

Generate one valid Airborne Velocity Message (Subtype 1) within 10 seconds following the last Airborne Position Message provided in Step 1. Verify that the reported Binary Report Mode field is set to "xxxx 0010."

2.4.8.2 Verification of the ADS-B Mode Status Report (§2.2.8.2)

Appropriate test procedures required to validate the requirements of §2.2.8.2 are included in the following subparagraphs.

2.4.8.2.1 Verification of the Mode Status Report Type and Structure Identification and Validity Flags (§2.2.8.2.1)

Appropriate test procedures are provided in §2.4.8.2.1.1 and §2.4.8.2.1.2.

2.4.8.2.1.1 Verification of Mode Status Report Type and Structure Identification (§2.2.8.2.1.1)

Purpose/Introduction:

The Report Type requirements are provided in §2.2.8.1.1. The Report Structure field is used to indicate the exact data parameters identified in Table 2-88 that are being provided in the Mode Status report and is intended to provide a methodology for implementers to structure concatenated reports when data for some parameters is not available. These test procedures verify the correct encoding of the Report Structure (Mode Status Report bits 5 through 24).

Equipment:

Provide a method of supplying the ADS-B Receiving Subsystem with valid ADS-B Messages.

Measurement Procedure:

Step 1: Incapability of Concatenation:

If the Report Assembly Function is implemented such that the Mode Status Report may be shortened when certain data is not available, skip to Step 2.

If the Report Assembly Function is implemented such that the Mode Status Report is 36 bytes long regardless of data availability across fields, consecutively provide the ADS-B Receiving Subsystem with valid ADS-B Messages, varying message types appropriately to prompt output of Mode Status Reports. Ensure that in each valid ADS-B Message provided to the ADS-B Receiving Subsystem, that the "AA" field (Message Bits 9 through 32) is set to hexadecimal A60DBE. Verify that in every Mode Status Report provided to the application, bytes 4 through 6 are hexadecimal A60DBE. Verify that the 24-bit Report Structure field is set to ALL ONEs in every Mode Status Report provided to the application. Verify that the Mode Status Report is 36 bytes long. This test procedure is now completed.

Step 2: Capability of Concatenation

Appropriate test procedures to validate this capability are provided in §2.4.8.2.4 through §2.4.8.2.18.

2.4.8.2.1.2 Verification of the Mode Status Report Validity Flags (§2.2.8.2.1.2)

Appropriate test procedures to validate the requirements of this section are provided in §2.4.8.2.4 through §2.4.8.2.18.

2.4.8.2.2 Verification of the Participant Address (§2.2.8.2.2)

Appropriate test procedures required to validate the Participant Address (§2.2.3.2.1.5) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.8.2.3 Verification of the Address Qualifier (§2.2.8.2.3)

Appropriate test procedures required to validate the requiremenets of §2.2.8.2.3 are included in §2.4.8.1.3.

2.4.8.2.4 Verification of the Mode Status Report – Report Time of Applicability (§2.2.8.2.4)

Purpose/Introduction:

These test procedures verify that each time that an Individual Mode Status Report is updated, the Report Assembly Function updates the Report Time of Applicability data in the Mode Status Report with either the GPS / GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Equipment:

The test equipment for this procedure depends on whether the ADS-B receiver under test is meant for Precision Installations or Non-Precision Installations (see §2.2.8.5). For Precision systems, the equipment will need to have the ability to provide GPS/GNSS UTC Measure Time Data via the appropriate interface. For Non-Precision systems, the equipment will include a clock that is appropriately synchronized with the internal clock of the ADS-B Receiving Subsystem. In both cases, the equipment **shall** have the capability to mark the time when a Mode Status Report is provided to the output buffer.

A method of providing valid ADS-B Messages that are used for constructing Mode Status Reports. Also, provide a method of providing valid Position and Velocity Messages to the ADS-B Receiving Subsystem. In all messages provided to the ADS-B receiver, regardless of type, the “AA” field (Message bits 9 through 32) will be set to the same discrete address. The requirement that the “AA” fields be identical is to ensure that the outputted Mode Status Reports are related solely to this test procedure.

Measurement Procedures:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Mode Status Reports to the Report Buffer.

Step 2: Verification of Report Time of Applicability

Provide any of the set of valid ADS-B Messages that are used in producing Mode Status Reports. After one second, provide a valid ADS-B Velocity Message to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function is prompted to output a Mode Status Report to the Report Buffer.

Mark the time—via GPS/GNSS UTC for Precision Installations, or the test clock for Non-Precision Installations. Retrieve the resulting Mode Status Report from the Report Buffer. Calculate the time represented in the “Report Time of

Applicability" (Report bytes 37 through 38 in the full Mode Status Report) and verify that this time is within 5ms of the previously marked time.

Repeat the process continuously for at least 550 seconds.

2.4.8.2.5 Verification of the Mode Status Report - Version Number (§2.2.8.2.5)

Purpose/Introduction:

The ADS-B Report Assembly Function must provide "Version Number" (see §2.2.3.2.7.2.5) data, as received in the Aircraft Operational Status Messages (see §2.2.3.2.7.2), when available, in the Mode Status Report. Otherwise, the Version Number must be assumed to be ZERO.

Measurement Procedure:

Step 1: Initialization

Be able to provide valid ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem, from ADS-B Transmitting Subsystems conforming to RTCA DO-260, RTCA DO-260A, and RTCA DO-260B such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Mode Status Reports to the Report Buffer.

Step 2: Verification of Version Number when Data is Not Available

Verify that the ADS-B Aircraft Operational Status Messages are being transmitted from a system conforming to RTCA DO-260. Receive the resulting Mode Status Report from the Report Buffer. Verify that the Version Number field (Report Byte 39 in the full Mode Status Report) is set to ALL ZEROs (binary 000).

Step 3: Verification of Version Number

Provide a valid ADS-B Aircraft Operational Status Message to the ADS-B Receiving Subsystem with the Version Number set as specified in Table 2-69, from an ADS-B Transmitting Subsystem conformant to RTCA DO-260B. Retrieve the resulting Mode Status Report from the Report Buffer. Verify that the Version Number presence bit (Report Byte 2, bit 4) is set to ONE. Verify that the Version Number field (Report Byte 39 in the full Mode Status Report) is set to TWO (binary 010).

2.4.8.2.6 Verification of the Mode Status Report - Call Sign (§2.2.8.2.6)

Purpose/Introduction:

The ADS-B Report Assembly Function must extract the Aircraft Identification Character subfields from the ADS-B Flight Identification and Category Message (§2.2.3.2.5.3) for further processing. Each character is encoded in a subset of International Alphabet No. 5 (IA-5) and formatted for the Mode Status Report in binary format specified in Table 2-88.

Equipment:

Provide a method of supplying Aircraft Identification Messages to the ADS-B Receiving Subsystem with the "Identification Character" subfields (Message bits 41 through 88) set as specified in Table 2-196. Also, provide a method of supplying Position and Velocity Messages to the ADS-B Receiving Subsystem. In all messages provided to the ADS-B receiver, regardless of type, the "AA" field (Message bits 9 through 32) will be set to the same discrete address. The requirement that the "AA" fields be identical is to ensure that the outputted Mode Status Reports are related solely to this test procedure.

Table 2-196: Mode Status Report Call Sign Encoding

Received Identification Character	Report Encoding
001100	01001100
011010	01011010
010110	01010110
010101	01010101
100000	00100000
110110	00110110
111001	00111001
111100	00111100
110111	00110111
110011	00110011
110101	00110101
000101	01000101
001011	01001011
000011	01000011
000001	01000001
001111	01001111
010001	00010001
011001	00011001

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Mode Status Reports to the Report Buffer.

Step 2: Verification of Call Sign Encoding when Data is Not Available

Retrieve the resulting Mode Status Report from the Report Buffer. If the Call Sign presence bit (Report Byte 0, bit 3) is set to ONE, verify that the "Call Sign" field (Report Bytes 7 through 14 in the full Mode Status Report) is set to ALL ZEROs.

Step 3: Verification of Participant Category Encoding

For each case in Table 2-196 above, provide a valid Aircraft Identification Message to the ADS-B Receiving Subsystem with each "Identification Character" subfield numbers 1 through 8 (Message bits 41 through 88) set to the same 6-bit encoding as specified in each entry of Table 2-196.

Retrieve the resulting Mode Status Report from the Report Buffer. Verify that the corresponding presence bit (Report Byte 0, bit 3) is set to ONE. Verify that each byte of the "Call Sign" field (Report Bytes 6 through 13 in the full Mode Status Report) is set to the correct value from the "Report Encoding" field of Table 2-196.

2.4.8.2.7 Verification of the Mode Status Report - Emitter Category (§2.2.8.2.7)

Purpose/Introduction:

The ADS-B Report Assembly Function must correctly determine the Emitter Category Encoding (Mode Status Report byte #19) from both "TYPE" and "ADS-B Emitter Category" information from the Aircraft Identification and Category Message (§2.2.3.2.5).

Equipment:

A method of providing Aircraft Identification and Category Messages to the ADS-B Receiving Subsystem with "TYPE" (Message bits 33 through 37) and "ADS-B Emitter Category" (Message bits 38 through 40) fields set as specified in Table 2-197. Also, provide a method of providing Position and Velocity Messages to the ADS-B Receiving Subsystem. In all messages provided to the ADS-B Receiving Subsystem, regardless of type, the "AA" field (Message bits 9 through 32) will be set to the same discrete address. The requirement that the "AA" fields be identical is to ensure that the outputted Mode Status Reports are related solely to this test procedure.

Table 2-197: Mode Status Report Emitter Category Meaning

TYPE	ADS-B Emitter Category	Encoding
4	0	0
4	1	1
4	2	3
4	3	5
4	4	6
4	5	7
4	6	8
4	7	10
3	0	0
3	1	11
3	2	12
3	3	16
3	4	15
3	6	13
3	7	14
2	0	0
2	1	20
2	2	21
2	3	22
1	0	0

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Mode Status Reports to the Report Buffer.

Step 2: Verification of Emitter Category Encoding when Data is Not Available

Retrieve the resulting Mode Status Report from the Report Buffer. If the Emitter Category presence bit (Report Byte 0, bit 0) is set to ONE, verify that the "Emitter Category" field (Report Byte 19 in the Mode Status Report) is set to ALL ZEROs.

Step 3: Verification of Emitter Category Encoding

For each case in Table 2-197 above, provide a valid Aircraft Identification and Category Message to the ADS-B Receiving Subsystem with "TYPE" (Message bits 33 through 37) and "ADS-B Emitter Category" (Message bits 38 through 40) fields set as specified in Table 2-197.

Retrieve the resulting Mode Status Report from the Report Buffer. When the "Encoding" field of Table 2-197 is not ZERO (0), verify that the corresponding presence bit (Report Byte 0, bit 0) is set to ONE. If the Emitter Category presence bit (Report Byte 0, bit 0) is set to ONE, verify that the "Emitter Category" field

(Report Byte 19 in the Mode Status Report) is set to the correct value from the "Encoding" field of Table 2-197.

2.4.8.2.8 Verification of the A/V Length and Width Code (§2.2.8.2.8)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the Aircraft/Vehicle (A/V) Length and Width Code from the Aircraft Operational Status Message (§2.2.3.2.7.2) when the A/V is on the airport surface. The A/V Length and Width Code is specified in Table 2-74, and is inserted into the Mode Status Report as specified in Table 2-88.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages, Version Zero (0) for Step 2, Version One (1) for Step 3 and Version Two (2) for step 4 to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of A/V Length & Width Code Data Not Available – Version Zero (0)

Provide valid Version Zero (0) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that bit 7 of byte 1 of the output Mode Status Report to the report buffer is set to ZERO (0).

Step 3: Verification of A/V Length & Width Code – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem such that the aircraft is in the On-Ground condition. Verify that for each input A/V Length & Width value from Table 2-74, that this value is reflected in the output Mode Status Report to the report buffer.

Step 4: Verification of A/V Length & Width Code – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem such that the aircraft is in the On-Ground condition. Verify that for each input A/V Length & Width value from Table 2-74, that this value is reflected in the output Mode Status Report to the report buffer.

2.4.8.2.9 Verification of the Mode Status Report - Emergency / Priority Status (§2.2.8.2.9)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the 3-bit "Emergency / Priority Status" data from the Extended Squitter Aircraft Status Message (§2.2.3.2.7.8) (TYPE=28, Subtype=1), and provides the Emergency / Priority Status information to the user application in the Mode Status Report in the binary format specified in Table 2-88 as specified in §2.2.8.2.9.

Equipment:

A method of providing Aircraft Status Messages with any and all possible bit-sets of Message Bits 9 through 11 to the ADS-B Receiving Subsystem. Also, provide a method of providing Position and Velocity Messages to the ADS-B Receiving Subsystem. In all messages provided to the ADS-B receiver, regardless of type, the "AA" field (Message bits 9 through 32) will be set to the same discrete address. The requirement that the "AA" fields be identical is to ensure that the outputted Mode Status Reports are related solely to this test procedure.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Mode Status Reports to the Report Buffer.

Step 2: Emergency / Priority Status - Not Available

Retrieve the resulting Mode Status Report from the Report Buffer. If the Emergency / Priority Status presence bit (Byte 1, bit 6) is set to ONE, verify that the three low order bits of the "Emergency / Priority Status" field (Report Byte 21 in the Mode Status Report) are set to ALL ZEROs.

Step 3: Verification of Emergency / Priority Status Encoding

Provide a valid ADS-B Extended Squitter Aircraft Status Message with Message bits 9 through 11 set to 0 (binary 000). After one second, provide a valid ADS-B Velocity Message such that a Mode Status Report is output to the Report Buffer.

Retrieve the resulting Mode Status Report from the Report Buffer. Verify that the Emergency / Priority Status presence bit (Byte 1, bit 6) is set to ONE (1). Verify that the "Emergency / Priority Status" field (Report Byte 21 in the Mode Status Report), bits 0, 1 and 2 are set identically to the provided Extended Squitter Aircraft Status Message bits 9, 10 and 11 respectively. Terminate the input for the Extended Squitter Aircraft Status Message and verify that the Mode Status Report continues to contain the last reported state of the Emergency/Priority Status for 100 seconds. After a period of 100 seconds, verify that the Emergency/Priority Status data field in the Mode Status Report contains ALL ZEROs, and that the

Emergency/Priority Status Validity Flag has been set in Byte 3, bit 2 (see Table 2-90) of the Mode Status Report to indicate that the data is not valid.

Step 4: Repeat

Repeat Step 3 above, setting the provided Extended Squitter Aircraft Status Message bits 9 through 11 to 1, 2, 3, 4 and 5 (binary 001, 010, 011, etc.). For each input, terminate the input for the Extended Squitter Aircraft Status Message and verify that the Mode Status Report continues to contain the last reported state of the Emergency/Priority Status for 100 seconds. After a period of 100 seconds, verify that the Emergency/Priority Status data field in the Mode Status Report contains ALL ZEROs, and that the Emergency/Priority Status Validity Flag has been set in Byte 3, bit 2 (see Table 2-90) of the Mode Status Report to indicate that the data is not valid.

2.4.8.2.10 Verfication of the Mode Status Report - Capability Class Codes (§2.2.8.2.10)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the "Capability Class Codes" data from the Aircraft Operational Status Message (§2.2.3.2.7.2) and provides the Capability Class Codes to the user application in the Mode Status Report in the binary format specified in Table 2-88 as specified in §2.2.8.2.10.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Mapping of CC Codes to the Mode Status Report – Version Zero (0)

Provide valid Version Zero (0) Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that bits 9-12 of the input "Capability Class Codes" data from these messages is mapped as per Table N-6 with the remaining bits in the three byte long Capability Class Codes field of the ADS-B Mode Status Report being set to ALL ZEROs.

Step 3: Verification of CC Codes – Data Not Available – Version Zero (0)

Provide valid Version Zero (0) ADS-B Messages but no Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that the Capability Class Codes Mode Status Data Parameter bit, bit 5 of byte 1 in the next output Mode Status Report, is set to ZERO (0).

Step 4: Verification of Mapping of CC Codes to the Mode Status Report – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that the input "Capability Class Codes" data from these messages is mapped bit for bit into the three byte long Capability Class Codes field of the ADS-B Mode Status Report as specified in Table 2-92.

Step 5: Verification of CC Codes – Data Not Available – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem without the CC Codes data included in the messages. Verify that the Capability Class Codes field of the ADS-B Mode Status Report is set to ALL ZEROs.

Step 6: Verification of Mapping of CC Codes to the Mode Status Report – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that the input "Capability Class Codes" data from these messages is mapped bit for bit into the three byte long Capability Class Codes field of the ADS-B Mode Status Report as specified in Table 2-92.

Step 7: Verification of CC Codes – Data Not Available – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem without the CC Codes data included in the messages. Verify that the Capability Class Codes field of the ADS-B Mode Status Report is set to ALL ZEROs.

2.4.8.2.11 Verification of the Mode Status Report - Operational Mode Data (§2.2.8.2.11)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the "Operational Mode" data, "ME" bits 25 through 40, (see Table 2-68 and §2.2.3.2.7.2.4) from the Aircraft Operational Status Message (§2.2.3.2.7.2) and maps it bit for bit into the 2-byte long (Report bytes 25 through 26) Operational Mode field of the ADS-B Mode Status Report in the binary format specified in Table 2-88.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification OM Data Omission – Version Zero (0)

Provide valid Version Zero (0) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that the Operational Mode Data Parameter bit, bit 4 of byte 1 in the next output Mode Status Report, is set to ZERO (0).

Step 3: Verification of Mapping OM Data to the MS Report – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that the input "Operational Mode" data from these messages is mapped bit for bit into the two byte long Operational Mode field of the ADS-B Mode Status Report as specified in Table 2-88.

Step 4: Verification of OM Codes – Data Not Available – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem without the OM data included in the messages. Verify that the Operational Mode field of the ADS-B Mode Status Report is set to ALL ZEROs.

Step 5: Verification of Mapping OM Data to the MS Report – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem. Verify that the input "Operational Mode" data from these messages is mapped bit for bit into the two byte long Operational Mode field of the ADS-B Mode Status Report as specified in Table 2-88.

Step 6: Verification of OM Codes – Data Not Available – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem without the OM data included in the messages. Verify that the Operational Mode field of the ADS-B Mode Status Report is set to ALL ZEROs.

2.4.8.2.12 Verification of the Mode Status Report - SV Quality – NAC_P (§2.2.8.2.12)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the NAC_P data from the Aircraft Operational Status Message (§2.2.3.2.7.2) and from the Target State and Status Message (§2.2.3.2.7.1.3.8) and maps the NAC_P value bit for bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Mapping NAC_P Data to the (MS) Report – Version Zero (0)

Provide valid ADS-B Messages with TYPE Codes equal to each of those specified in Table 2-188, in Version Zero format. Verify that the corresponding NAC_P value, as per Table 2-188, is mapped from the most recently received Version Zero ADS-B Message into the Mode Status Report as specified in Table 2-88.

Step 3: Verification of Data Not Available – Version Zero (0)

Provide valid Version Zero (0) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the NAC_P field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 5 of byte 3 is also set to ZERO (0).

Step 4: Verification of Mapping NAC_P Data to the (MS) Report – Version One (1)

Provide valid ADS-B Aircraft Operational Status and Target State and Status Messages to the ADS-B Receiving Subsystem in Version One (1) format. Verify that the input NAC_P data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 5: Verification of Data Not Available – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the NAC_P field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 5 of byte 3 is also set to ZERO (0).

Step 6: Verification of Mapping NAC_P Data to the (MS) Report – Version Two (2)

Provide valid ADS-B Aircraft Operational Status and Target State and Status Messages to the ADS-B Receiving Subsystem in Version Two (2) format. Verify that the input NAC_P data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 7: Verification of Data Not Available – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the NAC_P field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 5 of byte 3 is also set to ZERO (0).

2.4.8.2.13 Verification of the Mode Status Report - SV Quality – NAC_V (§2.2.8.2.13)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the NAC_V data from the ADS-B Airborne Velocity Message (§2.2.3.2.6) and maps the NAC_V value bit for bit from the received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Mapping NAC_V Data to the (MS) Report – Version Zero (0)

Provide valid ADS-B Airborne Velocity Messages to the ADS-B Receiving Subsystem in Version Zero (0) format. Verify that the input NUC_R data from these messages is mapped as NAC_V bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 3: Verification of Data Not Available – Version Zero (0)

Provide valid Version Zero (0) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the NUC_R field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 4 of byte 3 is also set to ZERO (0).

Step 4: Verification of Mapping NAC_V Data to the (MS) Report – Version One (1)

Provide valid ADS-B Airborne Velocity Messages to the ADS-B Receiving Subsystem in Version One (1) format. Verify that the input NAC_V data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 5: Verification of Data Not Available – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the NAC_V field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 4 of byte 3 is also set to ZERO (0).

Step 6: Verification of Mapping NAC_V Data to the (MS) Report – Version Two (2)

Provide valid ADS-B Airborne Velocity Messages to the ADS-B Receiving Subsystem in Version Two (2) format. Verify that the input NAC_V data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 7: Verification of Data Not Available – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the NAC_V field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 4 of byte 3 is also set to ZERO (0).

2.4.8.2.14 Verification of the Mode Status Report - SV Quality – SIL (§2.2.8.2.14)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the SIL, SIL_{SUPP} and System Design Assurance (SDA) data from the Aircraft Operational Status Message (§2.2.3.2.7.2.9) and/or from the Target State and Status Message (§2.2.3.2.7.1.3.10), and maps the SIL, SIL_{SUPP} and System Design Assurance (SDA) values bit for bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Mapping SIL Data to the (MS) Report – Version Zero (0)

Provide valid ADS-B Messages to the ADS-B Receiving Subsystem in Version Zero format with TYPE Codes equal to each of those specified in Table 2-188. Verify that the corresponding SIL value, as per Table 2-188, is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 3: Verification of Data Not Available – Version Zero (0)

Provide valid Version Zero (0) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the SIL field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 3 of byte 3 is also set to ZERO (0).

Step 4: Verification of Mapping NAC_V Data to the (MS) Report – Version One (1)

Provide valid ADS-B Aircraft Operational Status and Target State and Status Messages to the ADS-B Receiving Subsystem in Version One (1) format. Verify that the input SIL data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 5: Verification of Data Not Available – Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the SIL field of the ADS-B Mode Status Report is set to ALL ZEROs and that bit 3 of byte 3 is also set to ZERO (0).

Step 6: Verification of Mapping NAC_V Data to the (MS) Report – Version Two (2)

Provide valid ADS-B Aircraft Operational Status and Target State and Status Messages to the ADS-B Receiving Subsystem in Version Two (2) format. Verify that the input SIL, SIL_{SUPP} and System Design Assurance (SDA) data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 7: Verification of Data Not Available – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the SIL, SIL_{SUPP} and System Design Assurance (SDA) fields of the ADS-B Mode Status Report are set to ALL ZEROs and that bit 3 of byte 3 is also set to ZERO (0).

2.4.8.2.15 Verification of the Mode Status Report - SV Quality – GVA (§2.2.8.2.15)

Purpose/Introduction:

The ADS-B Report Assembly Function **shall** extract the GVA data from the Aircraft Operational Status Message (§2.2.3.2.7.2.8) and map the value of the GVA field to the Mode Status Report in the format specified in Table 2-88.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Mapping GVA Data to the (MS) Report – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Verify that the GVA data from these messages is mapped bit for bit from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 3: Verification of Data Not Available – Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages to the ADS-B Receiving Subsystem with valid TYPE Codes included in the messages. Allow 24 seconds to pass without an update and verify that the GVA field of the ADS-B Mode Status Report is set to ALL ZEROs.

Step 4: Verification of Previous Versions

No specific test procedure is required to validate the requirements for previous link versions as this field was reserved.

2.4.8.2.16 Verification of the Mode Status Report - SV Quality NIC_{BARO} (§2.2.8.2.16)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the NIC_{BARO} data from the Aircraft Operational Status Message (§2.2.3.2.7.2.10) and from the Target State and Status Message (§2.2.3.2.7.1.3.9), and maps the value of the NIC_{BARO} bit from the most recently received ADS-B Message to the Mode Status Report in the binary format specified in Table 2-88. The NIC_{BARO} field in the Mode Status Report uses the least significant bit of a one-byte field as a one-bit flag that indicates whether or not the barometric pressure altitude that is provided in the State Vector Report has been cross-checked against another source of altitude.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Mapping NIC_{BARO} Data to the (MS) Report – Version Zero (0)

Provide valid ADS-B Messages with TYPE Codes equal to each of those specified in Table 2-188, to the ADS-B Receiving Subsystem in Version Zero (0) format. Verify that the NIC_{BARO} Mode Status Data Parameter bit (bit 7 of byte 2) in the next output Mode Status Report, is set to ZERO (0).

Step 3: Verification of Mapping NAC_{BARO} Data to the (MS) Report – Version One (1)

Provide valid ADS-B Aircraft Operational Status and Target State and Status Messages to the ADS-B Receiving Subsystem in Version One (1) format. Verify that the input NIC_{BARO} data bit, the LSB from a one-byte field, from these messages is mapped directly from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

Step 4: Verification of Mapping NAC_{BARO} Data to the (MS) Report – Version Two (2)

Provide valid ADS-B Aircraft Operational Status and Target State and Status Messages to the ADS-B Receiving Subsystem in Version Two (2) format. Verify that the input NIC_{BARO} data bit, the LSB from a one-byte field, from these messages is mapped directly from the most recently received ADS-B Message to the Mode Status Report as specified in Table 2-88.

2.4.8.2.17 Verification of the Track/Heading and Horizontal Reference Direction (HRD) (§2.2.8.2.17)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the Track Angle/Heading (§2.2.3.2.7.2.12) and the Horizontal Reference Direction (HRD) (§2.2.3.2.7.2.13) flag bits from the Aircraft Operational Status Message (§2.2.3.2.7.2) and sets the True/Magnetic Heading field in the Mode Status Report in the binary format specified in Table 2-88. This item within the Mode Status Report is used to indicate the nature of the Horizontal Direction information being reported in the State Vector Reports. This applies to the aircraft reported Horizontal Direction (in the State Vector Report). The encoding of bits 0 and 1 of byte 32 of the Mode Status Report True/Magnetic Heading field is specified in Table 2-93. Bit 1 of the True/Magnetic Heading field indicates when Ground Track is being reported (i.e., set to zero) or when Heading is being reported (i.e., set to one). Bit 0 of the True/Magnetic Heading field indicates when Heading based on True North (i.e., set to zero) or when heading based on Magnetic North (i.e., set to one) is being reported.

Equipment Required:

Provide a method of providing Position and Velocity Messages to the ADS-B Receiving Subsystem. Also, provide a method of providing Aircraft Operational Status Messages with Version Number Bits (“ME” Bit 41 through 43, Message Bits 73 through 75) set to either ZERO (0) or ONE (1). In all messages provided to the ADS-B Receiving Subsystem, regardless of TYPE, the “AA” field (Message Bits 9 through 32) will be set to same discrete address. The requirement that "AA" fields be identical is to ensure that the outputted Mode Status Reports are related solely to this test procedure.

Measurement Procedures:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: No Track/Heading or HRD Information Available - Version Zero (0)

Provide valid Version Zero (0) ADS-B Surface Position Messages to the ADS-B Receiving Subsystem with the "Ground Track Status Bit" set to ZERO (0). Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ZERO (binary 00).

Provide valid Version Zero (0) ADS-B Airborne Velocity Messages with (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Magnetic Heading Status Bit" set to ZERO (0). Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ZERO (binary 00) in the next report.

Step 3: True Ground Track being reported - Version Zero (0)

Provide valid Version Zero (0) ADS-B Surface Position Messages to the ADS-B Receiving Subsystem with the "Ground Track Status Bit" set to One (1). Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ONE (binary 01).

Provide valid Version Zero (0) ADS-B Airborne Velocity Messages (Subtype=1 or 2) to the ADS-B Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ONE (binary 01).

Step 4: Heading relative to Magnetic North being reported - Version Zero (0)

Provide valid Version Zero (0) ADS-B Airborne Velocity Messages (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to One (1). Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to THREE (binary 11).

Step 5: No Track/Heading or HRD Information Available - Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages (Subtype=1) with "Track Angle/Heading Bit" set to ZERO (0) and Surface Position Messages with "Ground Track Status Bit" set to ZERO (0) to the ADS-B

Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ZERO (binary 00).

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages (Subtype=0) with "Track Angle/Heading Bit" set to One (1) and Airborne Velocity Messages with (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to ZERO (0). Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ZERO (binary 00).

Step 6: True Ground Track being reported - Version One (1)

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages (Subtype=1) with "Track Angle/Heading Bit" set to ZERO (0) and Surface Position Messages with "Ground Track Status Bit" set to ONE (1) to the ADS-B Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ONE (binary 01).

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages (Subtype=0) with "Track Angle/Heading Bit" set to ZERO (0) and Airborne Velocity Messages (Subtype=1 or 2) to the ADS-B Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ONE (binary 01).

Step 7: Heading relative to True North being reported - Version One (1)

Provide valid Version One (1) ADS-B Airborne Velocity Messages (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to One (1).

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages (Subtype=0) to the ADS-B Receiving Subsystem such that the Track Angle/Heading and HRD flag bits indicate Heading and True North. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to TWO (binary 10).

Step 8: Heading relative to Magnetic North being reported -Version One (1)

Provide valid Version One (1) ADS-B Airborne Velocity Messages (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to One (1).

Provide valid Version One (1) ADS-B Aircraft Operational Status Messages (Subtype=0) to the ADS-B Receiving Subsystem such that the Track Angle/Heading and HRD flag bits indicate Heading and Magnetic North. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to THREE (binary 11).

Step 9: No Track/Heading or HRD Information Available - Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages (Subtype=1) with "Track Angle/Heading Bit" set to ZERO (0) and Surface Position Messages with "Ground Track Status Bit" set to ZERO (0) to the ADS-B Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ZERO (binary 00).

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages (Subtype=0) with "Track Angle/Heading Bit" set to One (1) and Airborne Velocity Messages with (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to ZERO (0). Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ZERO (binary 00).

Step 10: True Ground Track being reported - Version Two (2)

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages (Subtype=1) with "Track Angle/Heading Bit" set to ZERO (0) and Surface Position Messages with "Ground Track Status Bit" set to ONE (1) to the ADS-B Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ONE (binary 01).

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages (Subtype=0) with "Track Angle/Heading Bit" set to ZERO (0) and Airborne Velocity Messages (Subtype=1 or 2) to the ADS-B Receiving Subsystem. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to ONE (binary 01).

Step 11: Heading relative to True North being reported - Version Two (2)

Provide valid Version Two (2) ADS-B Airborne Velocity Messages (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to One (1).

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages (Subtype=0) to the ADS-B Receiving Subsystem such that the Track Angle/Heading and HRD flag bits indicate Heading and True North. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to TWO (binary 10).

Step 12: Heading relative to Magnetic North being reported -Version Two (2)

Provide valid Version Two (2) ADS-B Airborne Velocity Messages (Subtype=3 or 4) to the ADS-B Receiving Subsystem with the "Heading Status Bit" set to One (1).

Provide valid Version Two (2) ADS-B Aircraft Operational Status Messages (Subtype=0) to the ADS-B Receiving Subsystem such that the Track Angle/Heading and HRD flag bits indicate Heading and Magnetic North. Verify that bits 0 and 1 of byte 32 of the True/Magnetic Heading field in the output Mode Status Report are set to THREE (binary 11).

2.4.8.2.18 Verification of the Mode Status Report - Vertical Rate Type (§2.2.8.2.18)

Purpose/Introduction:

These test procedures verify that the ADS-B Report Assembly Function properly extracts the Vertical Rate Source (§2.2.3.2.6.1.10, §2.2.3.2.6.2.10, §2.2.3.2.6.3.10, §2.2.3.2.6.4.10) data from the ADS-B Airborne Velocity Message (§2.2.3.2.6) and sets the Vertical Rate Type in the Mode Status Report in the binary format specified in Table 2-88. The Vertical Rate Type field uses the least significant bit of a one-byte field in the Mode Status Report. This one-bit flag is set to ZERO (0) to indicate that the Vertical Rate field in the State Vector Report holds the rate of change of barometric pressure altitude. Or, this one-bit flag is set to ONE (1) to indicate that the Vertical Rate field holds the rate of change of geometric altitude.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Code (bits 7 through 4 of byte 0) is set to TWO (binary 0010) to indicate Mode Status Report.

Step 2: Verification of Barometric Pressure Altitude – Version Zero (0)

Provide valid Version Zero (0) Airborne Velocity Messages to the ADS-B Receiving Subsystem such that Barometric Pressure Altitude is indicated. Verify that the LSB in byte 33 of the Mode Status Report is set to ZERO (0).

Step 3: Verification of Geometric Altitude – Version Zero (0)

Provide valid Version Zero (0) Airborne Velocity Messages to the ADS-B Receiving Subsystem such that Geometric Altitude is indicated. Verify that the LSB in byte 33 of the Mode Status Report is set to ONE (1).

Step 4: Verification of Barometric Pressure Altitude – Version One (1)

Provide valid Version One (1) Airborne Velocity Messages to the ADS-B Receiving Subsystem such that Barometric Pressure Altitude is indicated. Verify that the LSB in byte 33 of the Mode Status Report is set to ZERO (0).

Step 5: Verification of Geometric Altitude – Version One (1)

Provide valid Version One (1) Airborne Velocity Messages to the ADS-B Receiving Subsystem such that Geometric Altitude is indicated. Verify that the LSB in byte 33 of the Mode Status Report is set to ONE (1).

Step 6: Verification of Barometric Pressure Altitude – Version Two (2)

Provide valid Version Two (2) Airborne Velocity Messages to the ADS-B Receiving Subsystem such that Barometric Pressure Altitude is indicated. Verify that the LSB in byte 33 of the Mode Status Report is set to ZERO (0).

Step 7: Verification of Geometric Altitude – Version Two (2)

Provide valid Version Two (2) Airborne Velocity Messages to the ADS-B Receiving Subsystem such that Geometric Altitude is indicated. Verify that the LSB in byte 33 of the Mode Status Report is set to ONE (1).

2.4.8.2.19 Verification of the (Reserved for) Flight Mode Specific Data (§2.2.8.2.19)

Purpose/Inroduction:

A 3-bit field in the Mode Status Report is reserved for future use as a "Flight Mode Specific Data" field. In the current version of these MOPS, this field is set to ALL ZEROs.

Measurement Procedure:

Verify that in each Mode Status Report, the "Flight Mode Specific Data" field is ZERO.

2.4.8.3 Verification of the ADS-B On-Condition Report Characteristics (§2.2.8.3)

No specific test procedure is required to validate §2.2.8.3.

2.4.8.3.1 Verification of the Target State Report (§2.2.8.3.1)

Appropriate test procedures required to validate the requirements of §2.2.8.3.1 are included in the following subparagraphs.

2.4.8.3.1.1 Verification of the Target State Report Type and Structure Identification (§2.2.8.3.1.1)

Purpose/Introduction:

The Report Type requirements are provided in §2.2.8.1.1. The Report Structure field is used to indicate the exact data parameters identified in Table 2-88 that are being provided in the Target State Report and is intended to provide a methodology for implementers to structure concatenated reports when data for some parameters is not available. This test procedure will be used to verify the correct encoding of the Report Structure (Target State Report bits 5 through 21).

Equipment:

Provide a method of supplying the ADS-B Receiving Subsystem with valid ADS-B Messages.

Measurement Procedure:

Step 1: Incapability of Concatenation:

If the Report Assembly Function is implemented such that the Target State Report may be shortened when certain data is not available, skip to Step 2.

If the Report Assembly Function is implemented such that the Target State Report is 22 bytes long regardless of data availability across fields, consecutively provide the ADS-B Receiving Subsystem with valid ADS-B Messages, varying message types appropriately to prompt output of Target State Reports. Ensure that in each valid ADS-B Message provided to the ADS-B Receiving Subsystem, that the "AA" field (message bits 9 through 32) is set to hexadecimal A60DBE.

Verify that in every Target State Report provided to the application, bytes 2 through 4 are hexadecimal A60DBE. Verify that the 16-bit Report Structure field is set to ALL ONEs in every Target State Report provided to the application. Verify that the Target State Report is 22 bytes long. This test procedure is now completed.

Step 2: Capability of Concatenation

Appropriate test procedures to validate this capability are provided in §2.4.8.3.1.3 through §.

2.4.8.3.1.2 Verification of Target State and Status Validity Flags(§2.2.8.3.1.2)

Purpose/Introduction:

This test procedure is to verify the Validity Flags for data provided in the Target State Report as indicated in bytes #3 and #4 of the Target State Report shown for item "0c" in Table 2-95A.

Measurement Procedures:

Step 1: Initialization

Provide valid Airborne Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Target State Reports to the Report Buffer.

Step 2: Verification of Validity Flags

Provide valid Target State and Status Messages to the ADS-B Receiving Subsystem designed to trigger both valid and invalid validity flags via the indicated message bit(s) for mapping the following Target State Report elements in the appropriate bit in byte 3 of the Report as per Table 2-95A:

- MCP/FCU Selected Altitude or FMS Selected Altitude (ME bits 10-20 ALL ZEROES = Invalid, Non-ZERO = Valid)

- Barometric Pressure Setting (Minus 800 millibars) (ME bits 21-29 ALL ZEROES = Invalid, Non-ZERO = Valid)
- Selected Heading (ME bit 30)
- MCP/FCU Mode Bits Status (ME bit 47)

The ADS-B Report Assembly Function will be prompted to output a Target State Report to the Report Buffer. Verify that Target State Reports are generated where the validity flags are set to both ZERO and ONE at least one time each for MCP/FCU Selected Altitude or FMS Selected Altitude, Barometric Pressure Setting (Minus 800 millibars), Selected Heading and MCP/FCU Mode Bits Status.

2.4.8.3.1.3 Verification of the Participant Address (§2.2.8.3.1.3)

Appropriate test procedures to validate the Participant Address (§2.2.3.2.1.5) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.8.3.1.4 Verfication of the Address Qualifier (§2.2.8.3.1.4)

Appropriate test procedures required to validate the requirements of §2.2.8.3.1.4 are included in §2.4.8.1.3.

2.4.8.3.1.5 Verification of the Target State Report - Time of Applicability (§2.2.8.3.1.5)

Purpose/Introduction:

Each time that an Individual Target State Report is updated, the Report Assembly Function updates the Report Time of Applicability data in the Target State Report with either the GPS / GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

Equipment:

The test equipment for this procedure depends on whether the ADS-B receiver under test is meant for Precision Installations or Non-Precision Installations (see §2.2.8.5). For Precision systems, the equipment will need to have the ability to provide GPS/GNSS UTC Measure Time Data via the appropriate interface. For Non-Precision systems, the equipment will include a clock that is appropriately synchronized with the internal clock of the ADS-B Receiving Subsystem. In both cases, the equipment **shall** have the capability to mark the time when a Target State Report is provided to the output buffer.

A method of providing valid ADS-B Messages that are used for constructing Target State Reports. Also, provide a method of providing valid Position and Velocity Messages to the ADS-B Receiving Subsystem. In all messages provided to the ADS-B receiver, regardless of type, the "AA" field (Message bits 9 through 32) will be set to the same discrete address.

The requirement that the "AA" fields be identical is to ensure that the outputted Target State Reports are related solely to this test procedure.

Measurement Procedures:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting Target State Reports to the Report Buffer.

Step 2: Verification of Report Time of Applicability

Provide any valid Target State and Status Message. After one second, provide a valid ADS-B Velocity Message to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function is prompted to output a Target State Report to the Report Buffer.

Mark the time—via GPS/GNSS UTC for Precision Installations, or the test clock for Non-Precision Installations. Retrieve the resulting Target State Report from the Report Buffer. Calculate the time represented in the "Report Time of Applicability" (Report bytes 16 through 17 in the full Target State Report) and verify that this time is within 5 ms of the previously marked time.

Repeat the process continuously for at least 550 seconds.

2.4.8.3.1.6 Verification of Selected Altitude: Selected Altitude Type (§2.2.8.3.1.6)

Purpose/Introduction:

The Selected Altitude Type parameter uses the least significant bit within byte 10 to encode the parameter values specified in §2.2.3.2.7.1.3.2.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Selected Altitude: MCP/FCU

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem indicating the data source as MCP/FCU, i.e., ME bit 9 in the Target State and Status Message is set to ZERO. Verify that the corresponding Target State Report indicates an MCP/FCU source.

Step 3: Verification of Selected Altitude: FMS

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem indicating the data source as FMS, i.e., ME bit 9 in the Target State and Status Message is set to ONE. Verify that the corresponding Target State Report indicates an FMS source.

Step 4: Verification of Selected Altitude: Data Not Available

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem with ME bit 9 set to ZERO and ME bits 10-20 set to ALL ZEROs in the Target State and Status Message to indicate data not available. Verify that the corresponding Target State Report indicates data not available.

2.4.8.3.1.7 Verification of the Selected Altitude: MCP/FCU Selected Altitude or FMS Selected Altitude (§2.2.8.3.1.7)

Purpose/Introduction:

The MCP / FCU Selected Altitude or FMS Selected Altitude parameter uses the three (3) least significant bits within byte 11 and the 8 bits of byte 12 to encode the parameter values specified §2.2.3.2.7.1.3.3.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Selected Altitude: MCP/FCU Selected Altitude or FMS Selected Altitude

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bits 10 through 20 of the Target State and Status Message are mapped bit for bit to the Target State Report in the three least significant bits of byte 11 and all 8 bits of byte 12 of that report.

2.4.8.3.1.8 Verification of the Selected Altitude: Barometric Pressure Setting (Minus 800 millibars) (§2.2.8.3.1.8)

Purpose/Introduction:

The Barometric Pressure Setting (Minus 800 millibars) parameter uses the three (3) least significant bits within byte 13 and the 8 bits of byte 14 to encode the patameter values specified in §2.2.3.2.7.1.3.4.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Selected Altitude: Barometric Pressure Setting (Minus 800 millibars)

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bits 21-29 of the Target State and Status Message are mapped directly to the Target State Report in the least significant bit of byte 13 and the 8 bits of byte 14 of that report.

2.4.8.3.1.9 Verification of the Selected Heading (§2.2.8.3.1.9)

Purpose/Introduction:

The Selected Heading parameter uses the least significant bit of byte 15 and the 8 bits of byte 16 to encode the heading values specified in §2.2.3.2.7.1.3.7.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Selected Heading

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bits 31-39 of the Target State and Status Message are mapped directly to the Target State Report in the least significant bit of byte 15 and the 8 bits of byte 16 of that report.

2.4.8.3.1.10 Verification of the Mode Indicators: Autopilot Engaged (§2.2.8.3.1.10)

Purpose/Introduction:

The Autopilot Engaged parameter uses the least significant bit within byte 17 to encode the parameter values specified in §2.2.3.2.7.1.3.12.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Mode Indicators: Autopilot Engaged

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bit 48 of the Target State and Status Message is mapped to the Target State Report in the least significant bit of byte 17 of that report.

2.4.8.3.1.11 Verification of the Mode Indicators: VNAV Mode Engaged (§2.2.8.3.1.11)

Purpose/Introduction:

The VNAV Mode Engaged parameter uses the least significant bit within byte 18 to encode the parameter values specified in §2.2.3.2.7.1.3.13.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Mode Indicators: Autopilot engaged

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bit 49 of the Target State and Status Message is mapped to the Target State Report in the least significant bit of byte 18 of that report.

2.4.8.3.1.12 Verification of the Mode Indicators: Altitude Hold Mode (§2.2.8.3.1.12)

Purpose/Introduction:

The Altitude Hold Mode parameter uses the least significant bit within byte 19 to encode the parameter values specified in §2.2.3.2.7.1.3.14.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Mode Indicators: Altitude Hold Mode

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bit 50 of the Target State and Status Message is mapped to the Target State Report in the least significant bit of byte 19 of that report.

2.4.8.3.1.13 Verification of the Mode Indicators: Approach Mode (§2.2.8.3.1.13)

Purpose/Introduction:

The Approach Mode parameter uses the least significant bit within byte 20 to encode the parameter values specified in §2.2.3.2.7.1.3.16.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to THREE (binary 0011) to indicate Target State Report.

Step 2: Verification of Mode Indicators: Approach Mode

Provide a valid Target State and Status Message to the ADS-B Receiving Subsystem. Verify that ME bits 52 of the Target State and Status Message is mapped to the Target State Report in the least significant bit of byte 20 of that report.

2.4.8.3.1.14 Verification of the Reserved Byte (§2.2.8.3.1.14)

No specific test procedure is required to validate the requirement of §2.2.8.3.1.14.

2.4.8.3.2 Verification of the Air Referenced Velocity (ARV) Report (§2.2.8.3.2)

Appropriate test procedures required to validate the requirements of §2.2.8.3.2 are included in the following subparagraphs.

2.4.8.3.2.1 Verification of the ARV Report Type and Structure Identification and Validity Flags (§2.2.8.3.2.1)

No specific test procedure is required to validate §2.2.8.3.2.1.

2.4.8.3.2.1.1 Verification of the ARV Report Type and Structure Identification (§2.2.8.3.2.1.1)

Purpose/Introduction:

The Report Type requirements are provided in §2.2.8.1.1. The Report Structure field is used to indicate the exact data parameters identified in Table 2-88 that are being provided in the Target State Report and is intended to provide a methodology for implementers to structure concatenated reports when data for some parameters is not available. This test procedure will be used to verify the correct encoding of the Report Structure (ARV Report bits 6 through 13).

Equipment:

Provide a method of supplying the ADS-B Receiving Subsystem with valid ADS-B Messages.

Measurement Procedure:

Step 1: Incapability of Concatenation:

If the Report Assembly Function is implemented such that the ARV Report may be shortened when certain data is not available, skip to Step 2.

If the Report Assembly Function is implemented such that the ARV Report is 14 bytes long regardless of data availability across fields, consecutively provide the ADS-B Receiving Subsystem with valid ADS-B Messages, varying message types appropriately to prompt output of ARV Reports. Ensure that in each valid ADS-B Message provided to the receiver, the “AA” field (message bits 9 through 32) is set to hexadecimal A60DBE.

Verify that in every ARV Report provided to the application, bytes 3 through 5 are hexadecimal A60DBE. Verify that the 16-bit Report Structure field is set to ALL ONEs in every ARV Report provided to the application. Verify that the ARV Report is 14 bytes long.

Step 2: Capability of Concatenation

Appropriate test procedures to validate this capability are provided in §2.4.8.3.2.2 through §2.4.8.3.2.7.

2.4.8.3.2.1.2 Verification of the ARV Report Validity Flags (§2.2.8.3.2.1.2)

Purpose/Introduction:

The only Validity Flag specified by these MOPS for the Air Referenced Velocity Report uses the two (2) least significant bits of the one-byte field as shown in Table 2-98. These flags are set as specified in §2.2.8.3.2.1.2.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to FOUR (binary 0100) to indicate Air Referenced Velocity Report.

Step 2: Verification of Invalid Airspeed and Invalid Heading

Provide a valid Version ZERO (0) Aircraft Operational Status Message and an Airborne Velocity Message to the ADS-B Receiving Subsystem such that the "Heading Data is Not Available" and the Airspeed subfield indicates "No Airspeed Information Available" or the NAC_V / NUC_R (Version 1 / 0 respectively) Subfield is Invalid. Verify that the two least significant bits of byte 2 of the output ARV Report are both set to ZERO (binary 00).

Repeat this step with a Version ONE (1) Aircraft Operational Status Message and an Airborne Velocity Message and verify that the two least significant bits of byte 2 of the output ARV Report are both set to ZERO (binary 00).

Repeat this step with a Version TWO (2) Aircraft Operational Status Message and an Airborne Velocity Message and verify that the two least significant bits of byte 2 of the output ARV Report are both set to ZERO (binary 00).

Step 3: Verification of Invalid Airspeed and Valid Heading

Provide a valid Version ZERO (0) Aircraft Operational Status and an Airborne Velocity Message to the ADS-B Receiving Subsystem such that the "Heading Data is Valid" and the Airspeed subfield indicates "No Airspeed Information Available" or the NAC_V / NUC_R (Version 1 / 0 respectively) subfield is Invalid. Verify that the two least significant bits of byte 2 of the output ARV Report are set to ONE (binary 01).

Repeat this step with a Version ONE (1) Aircraft Operational Status Message and an Airborne Velocity Message and that the two least significant bits of byte 2 of the output ARV Report are set to ONE (binary 01).

Repeat this step with a Version TWO (2) Aircraft Operational Status Message and an Airborne Velocity Message and that the two least significant bits of byte 2 of the output ARV Report are set to ONE (binary 01).

Step 4: Verification of Valid Airspeed and Invalid Heading

Provide valid Airborne Velocity Message to the ADS-B Receiving Subsystem such that the "Heading Data is Not Available" and the Airspeed subfield indicates "A Valid Airspeed." Verify that the two least significant bits of byte 2 of the output ARV Report are set to TWO (binary 10).

Step 5: Verification of Valid Airspeed and Valid Heading

Provide valid Airborne Velocity Message to the ADS-B Receiving Subsystem such that the "Heading Data is Valid" and the Airspeed subfield indicates "A Valid Airspeed." Verify that the two least significant bits of byte 2 of the output ARV Report are set to THREE (binary 11).

2.4.8.3.2.2 Verification of the Participant Address (§2.2.8.3.2.2)

Appropriate test procedures to validate the Participant Address (§2.2.3.2.1.5) are included in the verification of the "PI" field in §2.4.3.2.1.7.

2.4.8.3.2.3 Verification of the Address Qualifier (§2.2.8.3.2.3)

Appropriate test procedures required to validate the requirements of §2.2.8.3.2.3 are included in §2.4.8.1.3.

2.4.8.3.2.4 Verification of the Report Time of Applicability (§2.2.8.3.2.4)

Purpose/Introduction:

Each time that an individual Air Referenced Velocity Report is updated, the Report Assembly Function updates the Time of Applicability data in the Air Referenced Velocity Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.5.1) or the Established Receiver Unit Time (see §2.2.8.5.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements. Report Time of Applicability data is provided in the Air Referenced Velocity report in binary format as specified in Table 2-96.

Equipment:

The test equipment for this procedure depends on whether the ADS-B receiver under test is meant for Precision Installations or Non-Precision Installations (see §2.2.8.5). For Precision systems, the equipment will need to have the ability to provide GPS/GNSS UTC Measure Time Data via the appropriate interface. For Non-Precision systems, the equipment will include a clock that is appropriately synchronized with the internal clock of the ADS-B Receiving Subsystem. In both cases, the equipment **shall** have the capability to mark the time when a Target State Report is provided to the output buffer.

A method of providing valid ADS-B Messages that are used for constructing Target State Reports. Also, provide a method of providing valid Position and Velocity Messages to the

ADS-B Receiving Subsystem. In all messages provided to the ADS-B receiver, regardless of type, the "AA" field (Message bits 9 through 32) will be set to the same discrete address. The requirement that the "AA" fields be identical is to ensure that the outputted Target State Reports are related solely to this test procedure.

Measurement Procedures:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State (see §2.2.10.4) and is outputting ARV Reports to the Report Buffer.

Step 2: Verification of Report Time of Applicability

Provide any valid Target State and Status Message. After one second, provide a valid ADS-B Velocity Message to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function is prompted to output an ARV Report to the Report Buffer.

Mark the time—via GPS/GNSS UTC for Precision Installations, or the test clock for Non-Precision Installations. Retrieve the resulting ARV Report from the Report Buffer. Calculate the time represented in the "Report Time of Applicability" (Report bytes 7 and 8 in the full ARV Report) and verify that this time is within 5 ms of the previously marked time.

Repeat the process continuously for at least 550 seconds.

2.4.8.3.2.5 Verification of the Airspeed (§2.2.8.3.2.5)

Appropriate test procedures required to validate the requirements of §2.2.8.3.2.5 are included in the following subparagraphs §2.4.8.3.2.5.1 and §2.4.8.3.2.5.2.

2.4.8.3.2.5.1 Verification of True Airspeed (TAS) Reporting (§2.2.8.3.2.5)

Purpose/Introduction:

These test procedures verify True Airspeed reported over the range of 0 to 4000 knots as specified in §2.2.8.3.2.5.

Measurement Procedure:

Step 1: True Air Speed (TAS) (Subsonic) Reporting

For each case in Table 2-198 below, generate valid ADS-B Airborne Velocity Messages (Subtype 3, Subsonic) which includes the Airspeed Type Bit ("ME" Bit 25) equal to "ONE," and the encoded data ("ME" Bits 26 through 35) for the Decimal True Air Speed (TAS) values listed in the table, and verify that the ADS-B Receiver/Report Assembly outputs ARV Reports

Verify that the corresponding Air Speed presence bit (Report Byte #0, Bit 2), and the Air Speed Validity Flag (Report Byte #2, Bit 1), are "ONEs."

Verify that the reported Binary Decoded TAS datum (Report Bytes #31 through 32) matches the corresponding True Air Speed value in the table.

Table 2-198: True Air Speed (Subsonic) Test Data

True Air Speed (Subsonic)	
Decimal True Air Speed (knots)	**Binary Decoded True Air Speed (Subsonic)**
0	0000 0000 0000 0000
1	0000 0000 0001 0000
2	0000 0000 0010 0000
4	0000 0000 0100 0000
8	0000 0000 1000 0000
16	0000 0001 0000 0000
32	0000 0010 0000 0000
64	0000 0100 0000 0000
128	0000 1000 0000 0000
256	0001 0000 0000 0000
512	0010 0000 0000 0000
1021	0011 1111 1101 0000

Step 2: True Air Speed (TAS) (Supersonic) Reporting

For each case in Table 2-199 below, generate valid ADS-B Airborne Velocity Messages (Subtype 4, Supersonic) which includes the Airspeed Type Bit ("ME" Bit 25) equal to "ONE," and the encoded data ("ME" Bits #26 through 35) for the Decimal True Air Speed (TAS) values listed in the table, and verify that the ADS-B Receiver/Report Assembly outputs ARV Reports.

Verify that the corresponding Air Speed presence bit (Report Byte #0, Bit 2), and the Air Speed Validity Flag (Report Byte #2, Bit 1), are "ONEs."

Verify that the reported Binary Decoded TAS datum (Report Bytes #31 through 32) matches the corresponding True Air Speed value in the table.

Table 2-199: True Air Speed (Supersonic) Test Data

True Air Speed (Supersonic)	
Decimal True Air Speed (knots)	**Binary Decoded True Air Speed (Supersonic)**
0	0000 0000 0000 0000
4	0000 0000 0100 0000
8	0000 0000 1000 0000
16	0000 0001 0000 0000
32	0000 0010 0000 0000
64	0000 0100 0000 0000
128	0000 1000 0000 0000
256	0001 0000 0000 0000
512	0010 0000 0000 0000
1024	0100 0000 0000 0000
2048	1000 0000 0000 0000
4084	1111 1111 0100 0000

Step 3: True Air Speed (TAS) (Subsonic / Supersonic) Data Not Available

Keep the Airspeed presence bit at "ONE," and set the Airspeed Validity Flag to "ZERO." Verify that the reported Binary Decoded TAS datum is set to all "ZEROs."

2.4.8.3.2.5.2 Verification of Indicated Airspeed (IAS) Reporting (§2.2.8.3.2.5)

Purpose/Introduction:

These test procedures verify Indicated Airspeed reported over the range of 0 to 4000 knots as specified in §2.2.8.3.2.5.

Measurement Procedure:

Step 1: Indicated Air Speed (IAS) (Subsonic) Reporting

For each case in Table 2-200 below, generate valid ADS-B Airborne Velocity Messages (Subtype 3, Subsonic) which includes the Airspeed Type Bit ("ME" Bit 25) equal to "ZERO," and the encoded data ("ME" Bits 26 through 35) for the Decimal Indicated Air Speed (IAS) values listed in the table, and verify that the ADS-B Receiver/Report Assembly outputs ARV Reports.

Verify that the corresponding Air Speed presence bit (Report Byte #0, Bit 2), and the Air Speed Validity Flag (Report Byte #2, Bit 1), are "ONEs."

Verify that the reported Binary Decoded IAS datum (Report Bytes # 33 through 34) matches the corresponding Indicated Air Speed value in the table.

Table 2-200: Indicated Air Speed (Subsonic) Test Data

Indicated Air Speed (Subsonic)	
Decimal Indicated Air Speed (knots)	**Binary Decoded Indicated Air Speed (Subsonic)**
0	0000 0000 0000 0000
1	0000 0000 0001 0000
2	0000 0000 0010 0000
4	0000 0000 0100 0000
8	0000 0000 1000 0000
16	0000 0001 0000 0000
32	0000 0010 0000 0000
64	0000 0100 0000 0000
128	0000 1000 0000 0000
256	0001 0000 0000 0000
512	0010 0000 0000 0000
1021	0011 1111 1101 0000

Step 2: Indicated Air Speed (IAS) (Supersonic) Reporting

For each case in Table 2-201 below, generate valid ADS-B Airborne Velocity Messages (Subtype 4, Supersonic) which includes the Airspeed Type Bit ("ME" Bit 25) equal to "ZERO," and the encoded data ("ME" Bits 26 through 35) for the Decimal Indicated Air Speed (IAS) values listed in the table, and verify that the ADS-B Receiver/Report Assembly outputs ARV Reports.

Verify that the corresponding Air Speed presence bit (Report Byte #0, Bit 2), and the Air Speed Validity Flag (Report Byte #2, Bit 1), are "ONEs."

Verify that the reported Binary Decoded IAS datum (Report Bytes # 33 through 34) matches the corresponding Indicated Air Speed value in the table.

Table 2-201: Indicated Air Speed (Supersonic) Test Data

Indicated Air Speed (Supersonic)	
Decimal Indicated Air Speed (knots)	**Binary Decoded Indicated Air Speed (Supersonic)**
0	0000 0000 0000 0000
4	0000 0000 0100 0000
8	0000 0000 1000 0000
16	0000 0001 0000 0000
32	0000 0010 0000 0000
64	0000 0100 0000 0000
128	0000 1000 0000 0000
256	0001 0000 0000 0000
512	0010 0000 0000 0000
1024	0100 0000 0000 0000
2048	1000 0000 0000 0000
4084	1111 1111 0100 0000

Step 3: Indicated Air Speed (IAS) (Subsonic / Supersonic) Data Not Available

Keep the Airspeed presence bit at "ONE," and set the Airspeed Validity Flag to "ZERO." Verify that the reported Binary Decoded IAS datum is set to all "ZEROs."

2.4.8.3.2.6 Verification of the Airspeed Type (§2.2.8.3.2.6)

Purpose/Introduction:

These test procedures verify that the Airspeed Type and Validity field in the Air Referenced Velocity Report is encoded as specified in Table 2-99. and §2.2.8.3.2.6.

Measurement Procedure:

Step 1: Initialization

Provide valid ADS-B Position and Velocity Messages to the ADS-B Receiving Subsystem such that the ADS-B Report Assembly Function enters the Track State and is outputting Reports to the Report Buffer. Verify that the Report Type Coding bits 7 through 4 of byte 0 are set to FOUR (binary 0100) to indicate Air Referenced Velocity Report.

Step 2: Verification of Airspeed Field Not Valid – Version Zero (0)

Provide a valid Version Zero (0) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield indicates "No Airspeed Available." Verify that the two least significant bits of byte 11 in the next ARV report are both set to ZERO (binary 00) and that the Airspeed Valid Flag, bit 1 of byte 2, is also set to ZERO (0). Send a second valid Version Zero (0) Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the NUC_R value is ZERO (0) and verify that the two least significant bits of byte 11 in the next ARV report are both set to ZERO (binary 00) and that the Airspeed Valid Flag, bit 1 of byte 2, is also set to ZERO (0). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 3: Verification of True Airspeed (TAS) – Version Zero (0)

Provide a valid Version Zero (0) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield is valid and indicates True Airspeed and where NUC_R has a non-zero value. Verify that the two least significant bits of byte 11 in the next ARV report are set to ONE (binary 01). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 4: Verification of Indicated Airspeed (IAS) – Version Zero (0)

Provide a valid Version Zero (0) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield is valid and indicates Indicated Airspeed and where NUC_R has a non-zero value. Verify that the two least significant bits of byte 11 in the next ARV report are set to TWO (binary 10). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 5: Verification of Airspeed Field Not Valid – Version One (1)

Provide a valid Version One (1) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield indicates "No Airspeed Available." Verify that the two least significant bits of byte 11 in the next ARV report are both set to ZERO (binary 00) and that the Airspeed Valid Flag, bit 1 of byte 2, is also set to ZERO (0). Send a second valid Version One (1) Airborne Velocity Message, Subtype 3 to the ADS-B Receiving Subsystem such that the NAC_V value is ZERO (0) and verify that the two least significant bits of byte 11 in the next ARV report are both set to ZERO (binary 00) and that the Airspeed Valid Flag, bit 1 of byte 2, is also set to ZERO (0). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 6: Verification of True Airspeed (TAS) – Version One (1)

Provide a valid Version One (1) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield is valid and indicates True Airspeed and where NAC_V has a non-zero value. Verify that the two least significant bits of byte 11 in the next ARV report are set to ONE (binary 01). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 7: Verification of Indicated Airspeed (IAS) – Version One (1)

Provide a valid Version One (1) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield is valid and indicates Indicated Airspeed and where NAC_V has a non-zero value. Verify that the two least significant bits of byte 11 in the next ARV report are set to TWO (binary 10). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 8: Verification of Airspeed Field Not Valid – Version Two (2)

Provide a valid Version Two (2) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield indicates "No Airspeed Available." Verify that the two least significant bits of byte 11 in the next ARV report are both set to ZERO (binary 00) and that the Airspeed Valid Flag, bit 1 of byte 2, is also set to ZERO (0). Send a second valid Version Two (2) Airborne Velocity Message, Subtype 3 to the ADS-B Receiving Subsystem such that the NAC_V value is ZERO (0) and verify that the two least significant bits of byte 11 in the next ARV report are both set to ZERO (binary 00) and that the Airspeed Valid Flag, bit 1 of byte 2, is also set to ZERO (0). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 9: Verification of True Airspeed (TAS) – Version Two (2)

Provide a valid Version Two (2) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield is valid and indicates True Airspeed and where NAC_V has a non-zero value. Verify that the two least significant bits of byte 11 in the next ARV report are set to ONE (binary 01). Repeat this step for two Subtype 4 Airborne Velocity Messages.

Step 10: Verification of Indicated Airspeed (IAS) – Version Two (2)

Provide a valid Version Two (2) Aircraft Operational Status and an Airborne Velocity Message - Subtype=3 to the ADS-B Receiving Subsystem such that the value in the "Airspeed" subfield is valid and indicates Indicated Airspeed and where NAC_V has a non-zero value. Verify that the two least significant bits of byte 11 in the next ARV report are set to TWO (binary 10). Repeat this step for two Subtype 4 Airborne Velocity Messages.

2.4.8.3.2.7 Verification of the Heading While Airborne (§2.2.8.3.2.7)

Purpose/Introduction:

These test procedures verify that the Aircraft's Heading is reported properly as specified in §2.2.8.3.2.7.

Measurement Procedure:

Step 1: Heading Reporting

For each case in Table 2-202 below, generate valid ADS-B Airborne Velocity Messages (TYPE=19, Subtype=3), which include the encoded data ("ME" Bits 14 and 15 through 24) for the "Heading Status Bit" and the Decimal "Heading" values listed, and verify that the ADS-B Receiver/Report Assembly outputs ARV Reports.

Verify that the corresponding "Heading" presence bit (Report Byte #0, Bit 0), and the Heading Validity Flag (Report Byte #2, Bit 0), are "ONEs."

Verify that the reported Binary Decoded Heading data (Report Bytes # 37 through 38) match the corresponding value in the table.

Table 2-202: "Heading" Subfield Test Data

Magnetic Heading		
Heading Status	**Decimal Heading (degrees)**	**Binary Decoded Heading**
0	11.2500	0000 0000 0000
0	359.6484	0000 0000 0000
1	0.0000	0000 0000 0000
1	0.3516	0000 0000 0001
1	0.7031	0000 0000 0010
1	1.4063	0000 0000 0100
1	2.8125	0000 0000 1000
1	5.6250	0000 0001 0000
1	11.2500	0000 0010 0000
1	22.5000	0000 0100 0000
1	45.0000	0000 1000 0000
1	90.0000	0001 0000 0000
1	180.0000	0010 0000 0000
1	359.6484	0011 1111 1111

Step 2: "Heading" Data Not Available

Keep the "Heading" presence bit at "ONE," and set the Heading Validity Flag to "ZERO." Verify that the reported Binary Decoded "Heading" datum is set to all "ZEROs."

2.4.8.4 Verification of the Processing of Reserved Message Types (§)

Verification of the processing of reserved ADS-B Message types is accomplished by including ADS-B Messages with TYPE Codes 24, 25, 26, 27 and 30 is the tests for State Vector (§2.4.8.1), Mode Status (§2.4.8.2) and On-Condition (§2.4.8.3) reports. See §2.4.8 for test scenario requirements.

2.4.8.5 Verification of the Receiving Installation Time Processing (§2.2.8.5)

No specific test procedure is required to validate §2.2.8.5.

2.4.8.5.1 Verification of Precision Installations (§2.2.8.5.1)

Purpose/Introduction:

These test procedures verify the requirements for precision installations as specified in §2.2.8.5.1.

Equipment:

A method of providing Surface Position Messages of TYPE 5 or 6 and Airborne Position Messages of TYPE 9, 10, 20 or 21 to the ADS-B Receiving Device. Also, a method of providing appropriate messages to prompt output of State Vector reports to the Report Buffer. All messages must have the "TIME" subfield set to ZERO.

Measurement Procedure:

Step 1: Verification of UTC Measure Time Data.

Configure the ADS-B Receiving device to output reports by providing the appropriate messages at the nominal rate, providing GPS/GNSS UTC Measure Time data appropriately. Mark TIME ZERO as the Time of Applicability provided in the first report. Note also the time that the message was provided that prompted the output of the first report.

Continue to provide messages at the nominal rate, extracting the Time of Applicability from each report that is outputted. Verify that time of applicability is properly reported within the accuracies of the established system clock.

300 seconds after the message that prompted the first report, provide a valid Surface Position Message with the TYPE subfield set to 5 or 6, and the TIME subfield set to ZERO.

Verify that in the resulting report, the Time of Applicability field does not reflect a value between TIME ZERO and 300 seconds.

Step 2: Repeat:

Repeat Step 1, using Airborne Position Messages of TYPE 9, 10, 20 or 21 instead of the previously specified Surface Position Messages.

2.4.8.5.2 Verification of the Non-Precision Installations (§2.2.8.5.2)

Purpose/Introduction

These test procedures verify the requirements for non-precision installations as specified in §2.2.8.5.2.

Equipment:

A method of providing Surface Position Messages of TYPE other than 5 or 6 and Airborne Position Messages of TYPE other than 9, 10, 20, or 21 to the ADS-B Receiving Device. Also, a method of providing appropriate messages to prompt output of State Vector reports to the Report Buffer. All messages must have the "TIME" subfield set to ZERO.

Measurement Procedure:

Step 1: Verification of Internal Clock Time Data.

Configure the ADS-B Receiving device to output reports by providing the appropriate messages at the nominal rate. Mark TIME ZERO as the Time of

Applicability provided in the first report. Note also the time that the message was provided that prompted the output of the first report.

Continue to provide messages at the nominal rate, extracting the Time of Applicability from each report that is outputted. Verify that time of applicability is properly reported within the accuracies of the established system clock.

300 seconds after the message that prompted the first report, provide a valid Surface Position Message with the TYPE subfield set to other than 5 or 6, and the TIME subfield set to ZERO.

Verify that in the resulting report, the Time of Applicability field does not reflect a value between TIME ZERO and 300 seconds.

Step 2: Repeat:

Repeat Step 1, using Airborne Position Messages of TYPE other than 9, 10, 20, or 21 instead of the previously specified Surface Position Messages.

2.4.9 Verification of the ADS-B Report Type Requirements (§2.2.9)

No specific test procedure is required to validate §2.2.9.

2.4.9.1 Verification of the ADS-B Receiver Reporting Requirements for Class A Equipage (§2.2.9.1)

Appropriate test procedures required to validate the requirements of §2.2.9.1 are included in §2.4.9.1.1 through §2.4.9.1.4.

2.4.9.1.1 Verification of the ADS-B State Vector Reports for Class A Equipage (§2.2.9.1.1)

The test procedures required to validate the requirements of §2.2.9.1.1 are included in §2.4.8.1.1 through §2.4.8.1.22.

2.4.9.1.2 Verification of the ADS-B Mode Status Reports for Class A Equipage (§2.2.9.1.2)

The test procedures required to validate the requirements of §2.2.9.1.2 are included in §2.4.8.2.1 through §2.4.8.2.18, and in the test steps that are identified below.

Purpose/Introduction:

Table 2-102 presents the required elements of a Mode Status Report. The Notes below the table indicate that several of those elements will continue to be reported in the Mode Status Report for a time period after the specifically referenced information has last appeared in its respective ADS-B Message. The following test procedure steps are intended to test that function.

Measurement Procedures:

Step 1: Perform the test steps in §2.4.8.2.6. Terminate the input for the ADS-B Aircraft Identification Message and verify that the Mode Status Report continues to contain the last reported state of the Call Sign for 200 seconds.

Step 2: Perform the test steps in §2.4.8.2.7. Terminate the input for the ADS-B Aircraft Identification Message and verify that the Mode Status Report continues to contain the last reported state of the Emitter Category for 200 seconds.

Step 3: Perform the test steps in §2.4.8.2.8. Terminate the input for the ADS-B Aircraft Operational Status Message and verify that the Mode Status Report continues to contain the last reported state of the A/V Length and Width Codes for 100 seconds.

Step 4: Perform the test steps in §2.4.8.2.10. Terminate the input for the ADS-B Aircraft Operational Status Messages and/or the ADS-B Target State and Status Messages, and verify that the Mode Status Report continues to contain the last reported state of the Capability Class Codes for 100 seconds.

Step 5: Perform the test steps in §2.4.8.2.11. Terminate the input for the ADS-B Aircraft Operational Status Messages and/or the ADS-B Target State and Status Messages, and verify that the Mode Status Report continues to contain the last reported state of the Operational Mode Codes for 100 seconds.

Step 6: Perform the test steps in §2.4.8.2.12. Terminate the input for the ADS-B Aircraft Operational Status Messages and/or the ADS-B Target State and Status Messages, and verify that the Mode Status Report continues to contain the last reported state of the NAC_P for 100 seconds.

Step 7: Perform the test steps in §2.4.8.2.13. Terminate the input for the ADS-B Airborne Velocity Messages and verify that the Mode Status Report continues to contain the last reported state of the NAC_V for 100 seconds.

Step 8: Perform the test steps in §2.4.8.2.14. Terminate the input for the ADS-B Aircraft Operational Status Messages and/or the ADS-B Target State and Status Messages, and verify that the Mode Status Report continues to contain the last reported state of the SIL for 100 seconds.

Step 9: Perform the test steps in §2.4.8.2.17. Terminate the input for the ADS-B Aircraft Operational Status Messages and verify that the Mode Status Report continues to contain the last reported state of the True/Magnetic Heading for 100 seconds.

Step 10: Perform the test steps in §2.4.8.2.18. Terminate the input for the ADS-B Airborne Velocity Messages and verify that the Mode Status Report continues to contain the last reported state of the Vertical Rate Type for 100 seconds.

2.4.9.1.3 Verification of the ADS-B Target State Reports for Class A Equipage (§2.2.9.1.3)

Purpose/Introduction:

These test procedures verify the requirements for Class A equipment to produce target State Reports, as specified in §2.2.9.1.3.

Measurement Procedure:

a. Equipage Class A0, A1S and A1 equipment are not required to comply with any of the test procedures in §2.4.8.3.

b. As a minimum, equipage Class A3 equipment **shall** perform test procedures outlined in §2.4.8.3.1.1 through §**Error! Reference source not found.** in order to validate the requirements of §2.2.9.1.3.b.

2.4.9.1.4 Verification of the ADS-B Air Referenced Velocity Reports for Class A Equipage (§2.2.9.1.4)

The test procedures required to validate the requirements of §2.2.9.1.4 are included in §2.4.8.3.2 through §2.4.8.3.2.7.

2.4.9.2 Verification of the ADS-B Receiver Report Content Requirements for Class B Equipage (§2.2.9.2)

There are no report requirements for Class B, i.e., Broadcast Only, Equipage.

No specific test procedure is required to validate §2.2.9.2.

2.4.10 Verification of the ADS-B Receiver Report Assembly and Delivery (§2.2.10)

No specific test procedure is required to validate §2.2.10.

2.4.10.1 Verification of the Fundamental Principals of Report Assembly and Delivery (§2.2.10.1)

No specific test procedure is required to validate §2.2.10.1.

2.4.10.1.1 Verification of the General Data Flow (§2.2.10.1.1)

No specific test procedure is required to validate §2.2.10.1.1.

2.4.10.1.2 Verification of the ADS-B Report Organization (§2.2.10.1.2)

Purpose/Introduction:

These test procedures verify that all ADS-B Message receptions and Reports are organized (i.e., indexed) in accordance with the Participant Address (see §2.2.3.2.1.1) and the Address Qualifier (see §2.2.8.1.3). The Participant Address and Address Qualifier are required elements in all ADS-B Reports (see Table 2-81 Items 1 and 2, Table 2-88 Items 1 and 2, Table 2-94 Items 1 and 2, and Table 2-96 Items 1 and 2).

Equipment Required:

a. Equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test through the operational interface.

b. A method of monitoring ADS-B broadcast messages output by the equipment under test.

Measurement Procedure:

Set the Airborne condition and load valid data into all the ADS-B Broadcast messages that can be supported by the equipment under test at a rate ensuring maximum transmission rate for a period of at least five (5) minutes. Ensure that ADS-B Messages will cause reports to be generated by the Report Assembly Function. Halt the transmission of ADS-B Messages and examine the contents of the database of messages and reports and verify that the messages and reports are being organized (i.e., indexed) in accordance with the Participant Address.

2.4.10.1.3 Verification of the ADS-B Message Temporary Retention (§2.2.10.1.3)

Purpose/Introduction:

These test procedures verify that, unless otherwise specified, all ADS-B Messages and decoded latitudes and longitudes received for a given Participant are appropriately time tagged and temporarily stored for at least 200 seconds unless replaced by a received message of equivalent type from that Participant. If no new messages have been received from a given Participant for 250 seconds, then all records (including temporary storage) relevant to the Participant Address will be deleted from the Report Output Storage Buffer.

Measurement Procedure:

Step 1: Airborne Mode – 25 Participants

Set up an Airborne scenario and simulation for a minimum of 25 Participants at various altitudes, velocities, initial positions and general directions. Design the simulation to include Participants that are traveling toward, away from, and crossing in the vicinity of, the ADS-B Receiving Device. The simulation must include several random Participants that appear for a short period of time of not less than fifteen (15), and not greater than twenty five (25) seconds, with accompanying issue of "***even***" and "***odd***" encoded Airborne Position Messages, and then disappear from the simulation altogether. These same Participants should be re-introduced to the simulation after an absence of at least 500 seconds.

Configure the ADS-B Transmitting Subsystem simulation to transmit Version Zero (0), Version One (1) and Version Two (2) Airborne Velocity Messages, Airborne Position Messages, Aircraft Identification and Category Messages, Aircraft Operational Status Messages, and Version One (1) and Version Two (2) Target State and Status Messages at a rate ensuring maximum transmission rate for a period of at least twenty (20) minutes.

Initiate the simulation and verify that all received data for a given individual Participant is being stored in temporary storage within a single track file. Verify that each entry contains a time tag. Verify that for those Participants that are continuing through out the simulation that updated information replaces old information upon the receipt of the new information. Verify that for those Participants that were introduced for a short period of time between 15 and 25 seconds that each track file for that Participant is retained for at least 250 seconds. Verify that if no new messages are received for a given Participant for a period of 250 seconds, that all data relevant to that Participant is deleted from the Report Output Storage Buffer.

Verify that when this same Participant is re-introduced to the simulation that the new set of data is stored in temporary storage and a new track file initiated with none of the data from the previous track.

Step 2: Surface Mode – 25 Participants

Set up a Surface scenario and simulation for a minimum of 25 Participants at various ground speeds, initial positions and general direction of travel. Design the simulation to include Participants that are traveling toward, away from, and crossing in the vicinity of, the ADS-B Receiving Device. The simulation must include random Participants that appear for a short period of time of not less than fifteen (15), and not greater than twenty five (25) seconds, and then disappear from the simulation altogether. This same Participant should be re-introduced to the simulation after an absence of at least 500 seconds.

Configure the ADS-B Transmitting Subsystem simulation to transmit Version Zero (0), Version One (1) and Version Two (2) Surface Position Messages, Aircraft Identification and Category Messages, and Aircraft Operational Status

Messages, at a rate ensuring maximum transmission rate for a period of at least twenty (20) minutes.

Initiate the simulation and verify that all received data for a given individual Participant is being stored in temporary storage within a single track file. Verify that each entry contains a time tag. Verify that for those Participants that are continuing through out the simulation that updated information replaces old information upon the receipt of the new information. Verify that for those Participants that were introduced for a short period of time between 15 and 25 seconds that each track file for that Participant is retained for at least 250 seconds. Verify that if no new messages are received for a given Participant for a period of 250 seconds, that all data relevant to that Participant is deleted from the Report Output Storage Buffer.

Verify that when this same Participant is re-introduced to the simulation that the new set of data is stored in temporary storage and a new track file initiated with none of the data from the previous track.

Step 3: Airborne Mode – 100 Participants

Repeat Step 1 above with a minimum of 100 individual Participants with various individual altitudes, velocities, initial positions and general directions.

2.4.10.1.4 Verification of the Participant ADS-B Track Files (§2.2.10.1.4)

Purpose/Introduction:

This test procedure verifies that the ADS-B Report Assembly function maintains one, and only one, Track File, i.e., set of reports on any given participant.

Measurement Procedure:

Verify that one, and only one Track file is created and maintained for each Participant.

2.4.10.2 Verification of the Report Assembly Initialization State (§2.2.10.2)

Appropriate test procedures for verifying that the Report Assembly Function correctly enters the “Initialization State” are provided in §2.4.10.1.3.

2.4.10.3 Verification of the Report Assembly Acquisition State (§2.2.10.3)

No specific test procedure is required to validate §2.2.10.3.

2.4.10.3.1 Verification of the Report Assembly Acquisition State --- Airborne Participant (§2.2.10.3.1)

Purpose/Introduction:

These test procedures verify that the Report Assembly Function properly establishes the Acquisition State for an Airborne Participant, as specified in §2.2.10.3.1.

Measurement Procedure:

Step 1: Globally Unambiguous CPR Decode

a. For each test case in Table 2.4.10.3.1, provide the CPR Decoder function with the "***odd***" and "***even***" Airborne Encodings. Provide the "***odd***" and "***even***" Encodings to the CPR Decoder function (see §A.1.7.7 of Appendix A) within ten (10) seconds of each other.

Table 2.4.10.3.1: Input Data for Global Unambiguous Airborne Decode Zone Checks

Input Data for Global Unambiguous Airborne Decode Zone Checks											
	Angular Weighted Binary (AWB) Position of the Encoder in Degrees				**Even Airborne Encoding**			**Odd Airborne Encoding**			
Test Case	**Latitude**		**Longitude**		**Lat.**	**Lon.**	**NL**	**Lat.**	**Lon.**	**NL**	
	(Decimal)	**(HEX)**	**(Decimal)**	**(HEX)**	**(HEX)**	**(HEX)**	**(Dec.)**	**(HEX)**	**(HEX)**	**(Dec.)**	
1	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0AFE0	10D8D	53	0D79C	033F0	53	
2	27.938976	13DE22A7	45.0000	20000000	15020	14000	53	12864	10000	53	
3	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0AFE0	033F0	**52**	0D79C	033F0	53	
4	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0AFE0	10D8D	53	0D79C	15A53	**52**	
5	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0AFE0	033F0	**52**	0D79C	15A53	**52**	

b. For test cases 1 and 2 in Table 2.4.10.3.1, verify that the CPR Decoder function (see §A.1.7.7 of Appendix A) provides an output **latitude** position within 0.00015 degrees of the **latitude** position indicated for test cases 1 and 2.

c. For test cases 1 and 2 in Table 2.4.10.3.1, verify that the CPR Decoder function (see §A.1.7.7 of Appendix A) provides an output **longitude** position within 0.00015 degrees of the **longitude** position indicated for test cases 1 and 2.

d. For test case 3 in Table 2.4.10.3.1, verify that the CPR Decoder function (see §A.1.7.7 of Appendix A) **does not** provide an output **longitude** position that is consistent with the **longitude** position indicated for test case 3.

Note: *The "**even**" encoding for test case 3 has been established by forcing the NL lookup to 52 for encoding as opposed to 53. This will result in significant error in the decoded position.*

e. For test case 4 in Table 2.4.10.3.1, verify that the CPR Decoder function (see §A.1.7.7 of Appendix A) **does not** provide an output **longitude** position consistent with the **longitude** position indicated for test case 4.

Note: *The "**odd**" encoding for test case 4 has been established by forcing the NL lookup to 52 for encoding as opposed to 53. This will result in significant error in the decoded position.*

f. For test case 5 in Table 2.4.10.3.1, verify that the CPR Decoder function (see §A.1.7.7 of Appendix A) **does not** provide an output **longitude** position consistent with the **longitude** position indicated for test case 5.

Note: *The "**odd**" and "**even**" encodings for test case 5 have been established by forcing the NL lookup to 52 for encoding as opposed to 53. This will result in the Decoder Function selecting NL "**odd**" equal to NL "**even**" and will produce what appears to be a valid decode of the position. However, the decoded position will not be consistent with the position indicated for test case 5 in Table 2.4.10.3.1.*

g. Using the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, verify that for each Participant for which an "***even***" and an "***odd***" pair of encoded Airborne Position Messages is received within a ten (10) second period that the Report Assembly Function correctly performs a successful Globally Unambiguous CPR Decode in accordance with §A.1.7.7 of Appendix A.

h. Add an Airborne Participant to the simulation whose decoded position is beyond the maximum operating range of the Own Ship position. Verify that the Report Mode of the Airborne Participant is returned to the Initialization State and that no State Vector Report is output. Verify that the remaining Airborne Participant tracks are not terminated because of the distance validation. Discontinue Own Ship position data so it is not available, and verify that no tracks are discarded by the position validation. Some of the simulation participants may be terminated due to lack of update.

Step 2: Report Mode set to Acquisition

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Airborne Position Message was received within a ten (10) second period that the Report Assembly Function correctly sets the Report Mode to "Acquisition" in the State Vector Report in accordance with the formatting specified in §2.2.8.1.22.

Step 3: State Vector Report Creation

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Airborne Position Message was received within a ten (10) second period that the Report Assembly Function correctly structures all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive).

Step 4: Report Output Storage Buffer Initialization

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Airborne Position Message was received within a ten (10) second period that the Report Assembly Function correctly delivers the first structured State Vector Report for the given Airborne Participant to the Report Output Storage Buffer for subsequent access by the Application Interface, within 500 milliseconds of receipt of the second Airborne Position Message of the "***even***" and "***odd***" pair for the given Airborne Participant.

Step 5: Maintenance of Report Output Storage Buffer

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Airborne Position Message was received within a ten (10) second period that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for at least 200 seconds unless:

a. replaced by an updated State Vector Report, or

b. no new messages have been received from a given Airborne Participant for a period of 100 ±5 seconds, in which case, verify that all reports relevant to the Airborne Participant Address have been deleted from the Report Output Storage Buffer.

Step 6: New Globally Unambiguous CPR Decode

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Airborne Position Message was received within a ten (10) second period that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for at least 200 seconds unless a new Airborne Position Message is received within a 120 second period for the given Airborne Participant.

Verify that when a new Airborne Position Message is received for a given Airborne Participant within a 120 second period, that the Report Assembly Function performs a new Globally Unambiguous CPR Decode as specified in Step 1 above and verify that the new information is correctly updated in the State Vector Report and the Report Output Storage Buffer for the given Airborne Participant.

Verify that when no new Airborne Position Message is received for a given Airborne Participant within a 120 second period, that the Report Assembly Function correctly sets the Report Mode to "Initialization" (No Report Generation

Capability mode) in the State Vector Report in accordance with the formatting in §2.2.8.1.22.

Step 7: Purge Participant from the Report Output Storage Buffer

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Airborne Position Message was received within a ten (10) second period that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for at least 200 seconds unless replaced by an updated State Vector Report for the given Airborne Participant

Verify that when no new Messages of any type have been received from a given Airborne Participant for at least 200 seconds, that the Report Assembly Function correctly deletes all reports relevant to the given Airborne Participant Address from the Report Output Storage Buffer.

2.4.10.3.1.1 Verification of the Latency, Report Assembly Acquisition State --- Airborne Participant (§2.2.10.3.1.1)

Purpose/Introduction:

This test procedure verifies that Step "d" in §2.2.10.3.1 is completed within 500 milliseconds of receipt of the second Airborne Position Message of the "***even***" and "***odd***" pair.

Measurement Procedure:

Appropriate test procedures for the verification of this requirement are provided in §2.4.10.3.1, Step 4.

2.4.10.3.2 Verification of the Report Assembly Acquisition State --- Surface Participant (§2.2.10.3.2)

Purpose/Introduction:

These test procedures verify that the Report Assembly Function properly establishes the Acquisition State for a Surface Participant, as specified in §2.2.10.3.2.

Measurement Procedure:

Step 1: Globally Unambiguous CPR Decode

a. For each test case in Table 2.4.10.3.2, provide the CPR Decoder function with the "***odd***" and "***even***" Surface Encodings. Provide the "***odd***" and "***even***" Encodings to the CPR Decoder function (see §A.1.7.8 of Appendix A) within fifty (50) seconds of each other.

Table 2.4.10.3.2: Input Data for Global Unambiguous Surface Decode Zone Checks

Input Data for Global Unambiguous Surface Decode Zone Checks											
	Angular Weighted Binary (AWB)Position of the Encoder in Degrees				Even Surface Encoding			Odd Surface Encoding			
Test Case	Latitude		Longitude		Lat.	Lon.	NL	Lat.	Lon.	NL	
	(Decimal)	(HEX)	(Decimal)	(HEX)	(HEX)	(HEX)	(Dec.)	(HEX)	(HEX)	(Dec.)	
1	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0BF7F	03636	53	15E70	0CFC1	53	
2	27.938976	13DE22A7	45.0000	20000000	14081	10000	53	0A190	00000	53	
3	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0BF7F	0CFC1	**52**	15E70	0CFC1	53	
4	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0BF7F	03636	53	15E70	1694C	**52**	
5	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0BF7F	0CFC1	**52**	15E70	1694C	**52**	

b. For test cases 1 and 2 in Table 2.4.10.3.2, verify that the CPR Decoder function (see §A.1.7.8 of Appendix A) provides an output **latitude** position within 0.00015 degrees of the **latitude** position indicated for test cases 1 and 2.

c. For test cases 1 and 2 in Table 2.4.10.3.2, verify that the CPR Decoder function (see §A.1.7.8 of Appendix A) provides an output **longitude** position within 0.00015 degrees of the **longitude** position indicated for test cases 1 and 2.

d. For test case 3 in Table 2.4.10.3.2, verify that the CPR Decoder function (see §A.1.7.8 of Appendix A) **does not** provide an output **longitude** position consistent with the **longitude** position indicated for test case 3.

Note: *The "**even**" encoding for test case 3 has been established by forcing the NL lookup to 52 for encoding as opposed to 53. This will result in significant error in the decoded position.*

e. For test case 4 in Table 2.4.10.3.2, verify that the CPR Decoder function (see §A.1.7.8 of Appendix A) **does not** provide an output **longitude** position consistent with the **longitude** position indicated for test case 4.

Note: *The "**odd**" encoding for test case 4 has been established by forcing the NL lookup to 52 for encoding as opposed to 53. This will result in significant error in the decoded position.*

f. For test case 5 Table 2.4.10.3.2, verify that the CPR Decoder function (see §A.1.7.8 of Appendix A) **does not** provide an output **longitude** position consistent with the **longitude** position indicated for test case 5.

Note: *The "**odd**" and "**even**" encodings for test case 5 have been established by forcing the NL lookup to 52 for encoding as opposed to 53. This will result in the Decoder Function selecting NL "odd" equal to NL "even" and will produce what appears to be a valid decode of the position. However, the decoded position will not be consistent with the position indicated for row 5 in Table 2.4.10.3.2.*

g. Using the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, verify that for each Participant for which an "***even***" and an "***odd***" pair of encoded Surface Position Messages is received within a twenty five (25) second period that the Report Assembly Function correctly performs a successful Globally Unambiguous CPR Decode in accordance with §A.1.7.8 of Appendix A. Input surface targets with speeds greater than 25 knots and verify that when "***even***" and "***odd***" Position Messages are spaced more than 25 seconds apart, that a successful Globally Unambiguous CPR Decode is not completed for such targets. Input surface targets with speeds less than 25 knots that have "***even***" and "***odd***" Position Messages spaced between 25 and 50 seconds and verify that the Report Assembly Function correctly performs a successful Globally Unambiguous CPR Decode in accordance with §A.1.7.8 of Appendix A. Input surface targets with speeds less than 25 knots that have "***even***" and "***odd***" Position Messages spaced greater than 50 seconds apart and verify that the Report Assembly Function does not complete a successful Globally Unambiguous CPR Decode for such targets.

h. Add a Surface Participant to the simulation whose decoded position is beyond the maximum operating range of the Own Ship position. Verify that the Report Mode of the Surface Participant is returned to the Initialization State and that no State Vector Report is output. Verify that the remaining Surface Participant tracks are not terminated because of the distance validation. Discontinue Own Ship position data so it is not available and verify that no tracks are discarded by the position validation. Some of the simulation participants may be terminated because of lack of update.

<u>Step 2:</u> <u>Report Mode set to Track</u>

Verify that for each Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Surface Position Message was received, within the proper time interval based on the speed of the Participant, that the Report Assembly Function correctly sets the Report Mode to "Track" in the State Vector Report in accordance with the formatting specified in §2.2.8.1.22.

<u>Step 3:</u> <u>State Vector Report Creation</u>

Verify that for each Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Surface Position Message was received, within the proper time interval based on the speed of the Participant, that the Report Assembly Function correctly structures all possible fields of the State Vector Report for the given Surface Participant in accordance with §2.2.8.1 (all subsections inclusive).

<u>Step 4:</u> <u>Report Output Storage Buffer Initialization</u>

Verify that for each Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Surface Position Message was received, within the proper time interval based on the speed of the Participant, that the Report

Assembly Function correctly delivers the first structured State Vector Report for the given Surface Participant to the Report Output Storage Buffer for subsequent access by the Application Interface, within 500 milliseconds of receipt of the second Surface Position Message of the "***even***" and "***odd***" pair for the given Surface Participant.

Step 5: Maintenance of Report Output Storage Buffer

Verify that for each Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Surface Position Message was received, within the proper time interval based on the speed of the Participant, that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Surface Participant in the Report Output Storage Buffer for at least 200 seconds unless:

a. Replaced by an updated State Vector Report, or

b. No new messages have been received from a given Surface Participant for a period of 100 ±5 seconds, in which case, verify that all reports relevant to the Surface Participant Address have been deleted from the Report Output Storage Buffer.

Step 6: New Locally Unambiguous CPR Decode

Verify that for each Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Surface Position Message was received, within the proper time interval based on the speed of the Participant, that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Surface Participant in the Report Output Storage Buffer for at least 200 seconds unless a new Surface Position Message is received within a 120 second period for the given Surface Participant.

Verify that when a new Surface Position Message is received for a given Surface Participant within a 120 second period, that the Report Assembly Function performs a new Locally Unambiguous CPR Decode as specified in Step 1 above and verify that the new information is correctly updated in the State Vector Report and the Report Output Storage Buffer for the given Surface Participant.

Step 7: Purge Participant from the Report Output Storage Buffer

Verify that for each Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified in Step 1 above that an "***even***" and an "***odd***" encoded Surface Position Message was received, within the proper time interval based on the speed of the Participant, that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Surface Participant in the Report Output Storage Buffer for at least 200 seconds unless replaced by an updated State Vector Report for the given Surface Participant.

Verify that when no new Messages of any type have been received from a given Surface Participant for at least 200 seconds, that the Report Assembly Function correctly deletes all reports relevant to the given Surface Participant Address from the Report Output Storage Buffer.

2.4.10.3.2.1 Verification of the Latency, Report Assembly Acquisition State --- Surface Participant (§2.2.10.3.2.1)

Purpose/Introduction

Step "d" in §2.2.10.3.2 is to be completed within 500 milliseconds of receipt of the second Surface Position Message of the "***even***" and "***odd***" pair.

Measurement Procedure:

Appropriate test procedures for the verification of this requirement are provided in §2.4.10.3.2, Step 4.

2.4.10.3.3 Verification of the Acquisition State Data Retention (§2.2.10.3.3)

Purpose/Introduction:

This test procedure verifies that the Report Assembly Function properly retains the ADS-B Message data as specified in §2.2.10.3.3.

Measurement Procedure:

Upon receipt of any of the messages identified in §2.2.10.2 for any given Participant, verify that the Report Assembly Function checks to ensure that it has not received one half (either "***even***" or "***odd***") of a position message pair from this Participant within a ten second period.

Verify that when the receipt of the message is determined to be the second half (either "***even***" or "***odd***") of a position message pair from this Participant, that the Report Assembly Function uses the message as specified using the Test Procedures in §2.4.10.3.1 for Airborne Participants, or §2.4.10.3.2 for Surface Participants.

If the receipt of the message is determined to NOT be the second half of a position message, then verify that the Report Assembly Function uses the message as specified in using the Test Procedures in §2.4.10.1.3.

2.4.10.4 Verification of the Report Assembly Track State (§2.2.10.4)

No specific test procedure is required to validate §2.2.10.4.

2.4.10.4.1 Verification of the Report Assembly Track State - Airborne Participant (§2.2.10.4.1)

No specific test procedure is required to validate §2.2.10.4.1.

2.4.10.4.1.1 Verification of the Report Assembly Track State Initialization - Airborne Participant (§2.2.10.4.1.1)

Purpose/Introduction:

These test procedures verify that the Report Assembly Function properly establishes the Track State for an Airborne Participant as specified in §2.2.10.4.1.1.

Measurement Procedure:

Step 1: Locally Unambiguous CPR Decode and Set the Report Mode to Track

a. For each test case in Table 2.4.10.4.1.1, provide the CPR Decoder function (see §A.1.7.5 of Appendix A) with the "***odd***" and "***even***" Airborne Encodings within five (5) seconds of each other.

Table 2.4.10.4.1.1: Input Data for Local Unambiguous Airborne Decode Zone Checks

Input Data for Local Unambiguous Airborne Decode Zone Checks										
	Angular Weighted Binary (AWB)Position of the Encoder in Degrees				**Even Airborne Encoding**			**Odd Airborne Encoding**		
Test Case	**Latitude**		**Longitude**		**Lat.**	**Lon.**	**NL**	**Lat.**	**Lon.**	**NL**
	(Decimal)	**(HEX)**	**(Decimal)**	**(HEX)**	**(HEX)**	**(HEX)**	**(Dec.)**	**(HEX)**	**(HEX)**	**(Dec.)**
1	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0AFEO	10D8D	53	0D79C	033F0	53

b. Verify that the CPR Decoder function (see §A.1.7.5 of Appendix A) provides an "***even***" and "***odd***" output **latitude** position within 0.00015 degrees of the **latitude** position indicated for the test case in Table 2.4.10.4.1.1.

c. Verify that the CPR Decoder function (see §A.1.7.5 of Appendix A) provides an "***even***" and "***odd***" output **longitude** position within 0.00015 degrees of the **longitude** position indicated for the test case in Table 2.4.10.4.1.1.

d. Start this test procedure step with the assumption that for a given Airborne Participant, the Acquisition State has been established in accordance with the Test Procedures in §2.4.10.3.1.

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Acquisition State has been established, and upon receipt of the first Airborne Velocity Message for the given Participant, verify that the Report Assembly Function correctly sets the Report Mode to "Track" in the State Vector Report in accordance with the formatting in §2.2.8.1.22.

Step 2: Update State Vector Report

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Acquisition State has been established, and upon receipt of the first Airborne Velocity Message for the given Participant, verify that the Report Assembly Function correctly structures all possible fields in the State Vector Report in accordance with §2.2.8.1(all subsections inclusive).

Step 3: Update the Report Output Storage Buffer

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Acquisition State has been established, and upon receipt of the first Airborne Velocity Message for the given Participant, verify that the Report Assembly Function correctly structures all possible fields in the State Vector Report in accordance with §2.2.8.1 (all subsections inclusive).

Verify that the updated State Vector Report is delivered to the Report Output Storage Buffer within 500 milliseconds of the receipt of the first Airborne Velocity Message for the given Participant.

Step 4: Maintenance of Report Output Storage Buffer

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Acquisition State has been established, and upon receipt of the first Airborne Velocity Message for the given Participant, verify that the Report Assembly Function correctly maintains the integrity of the State Vector Report for the given Participant in the Report Output Storage Buffer for a period of 100 ±5 seconds unless replaced by an updated State Vector Report.

Step 5: Initiate Assembly of the Mode Status Report

a. Upon receipt of the first Airborne Velocity Message from the Participant, and the “Track” State has been entered as in Steps 1 through 3 above, verify that the Report Assembly Function initiates a complete review of all messages received for the given Participant that have been placed in temporary storage in accordance with §2.2.10.1.3.

b. Upon completion of the review of all messages for the given Participant, verify that the Report Assembly Function correctly structures all possible fields of the Mode Status Report for the given Participant in accordance with §2.2.8.2 (all subsections inclusive).

c. Verify that the Mode Status Report is delivered to the Report Output Storage Buffer within 500 milliseconds of the receipt of the first Airborne Velocity Message that caused the initialization of the “Track” State for the given Participant.

d. Verify that the integrity of the Mode Status Report is maintained for the given Participant in the Report Output Storage Buffer for a period of 100 ±5 seconds, unless replaced by an updated Mode Status Report for that Participant.

Step 6: Initiate Assembly of ADS-B Target State Report

a. Upon receipt of the first Airborne Velocity Message from the Participant, and the "Track" State has been entered as in Steps 1 through 3 above, verify that the Report Assembly Function initiates a complete review of all messages received for the given Participant that have been placed in temporary storage in accordance with §2.2.10.1.3.

b. Upon completion of the review of all messages for the given Participant, verify that the Report Assembly Function correctly structures all possible fields of the ADS-B Target State Report for the given Participant in accordance with §2.2.8.3 (all subsections inclusive).

c. Verify that the ADS-B Target State Report is delivered to the Report Output Storage Buffer within 500 milliseconds of the receipt of the first Airborne Velocity Message that caused the initialization of the "Track" State for the given Participant.

d. Verify that the integrity of the ADS-B Target State Report is maintained for the given Participant in the Report Output Storage Buffer for a period of 100 ±5 seconds, unless replaced by an updated ADS-B Target State Report for that Participant.

2.4.10.4.1.2 Verification of the Report Assembly Track State Maintenance - Airborne Participant (§2.2.10.4.1.2)

Purpose/Introduction:

These test procedures verify that the Track State is maintained for a given Airborne Participant for as long as Airborne Position Messages (see §2.2.3.2.3) and Airborne Velocity Messages (see §2.2.3.2.6) are being received from the Participant, as specified in §2.2.10.4.1.2.

Measurement Procedure:

Step 1: Receipt of a new Airborne Position Message

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, and upon the receipt of a new Airborne Position Message for the given Participant, verify that the Report Assembly Function correctly:

a. performs a locally unambiguous CPR decode of the Airborne Participant position in accordance with §A.1.7.4 and §A.1.7.5 of Appendix A, and that the reasonableness test defined in §2.2.10.6.3 is performed, and that the track is updated if the difference in the position decodes resulting from the reasonableness test are less than or equal to 6 NM, if the last Position Message received was an Airborne Position Message, or less than or equal to 2.5 NM if the last Position Message received was a Surface Position Message.

However, if the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the reported position in the most recently received Position Message differs from the previously reported position by more than 6 NM if the last Position Message received was an Airborne Position Message, or more than 2.5 NM if the last Position Message received was a Surface Position Message, then the most recently received position **is not** used to update the track.

b. updates all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive).

c. delivers the updated State Vector Report to the Report Output Storage Buffer within 500 milliseconds of the receipt of the new Airborne Position Message.

d. maintains the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated State Vector Report.

Step 2: Receipt of a new Airborne Velocity Message

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, and upon the receipt of a new Airborne Velocity Message for the given Participant, verify that the Report Assembly Function correctly:

a. updates all possible fields of the State Vector Report for the given Airborne Participant in accordance with §2.2.8.1 (all subsections inclusive).

b. delivers the updated State Vector Report to the Report Output Storage Buffer within 500 milliseconds of the receipt of the new Airborne Velocity Message.

c. maintains the integrity of the State Vector Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated State Vector Report.

Step 3: Receipt of other Messages while in Track State and Creating a Mode Status

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, and upon the receipt of a new Aircraft Identification and Category Message, Target State and Status Message, Aircraft Operational Status Message, or Aircraft Status Message for the given Participant, verify that the Report Assembly Function correctly:

a. updates all possible fields of the Mode Status Report for the given Airborne Participant in accordance with §2.2.8.2 (all subsections inclusive).

b. delivers the updated Mode Status Report to the Report Output Storage Buffer within 500 milliseconds of the receipt of the new Message.

c. maintains the integrity of the Mode Status Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated Mode Status Report.

Step 4: Creating a Target State Report

Verify that for each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, and upon the receipt of a new Target State and Status Message having Target State information, for the given Participant, verify that the Report Assembly Function correctly:

a. updates all possible fields of the Target State Report for the given Airborne Participant in accordance with §2.2.8.3 (all subsections inclusive).

b. delivers the updated Target State Report to the Report Output Storage Buffer within 500 milliseconds of the receipt of the new Message.

c. maintains the integrity of the Target State Report for the given Airborne Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replaced by an updated Target State Report.

Step 5: Creating an Air Referenced Velocity Report

Verify that for each participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that Track State has been established, and upon the receipt of a new Airborne Velocity Message, Subtype 3 or 4 containing Air Referenced Velocity information for the given Participant, verify that the Report Assembly Function correctly:

a. updates all possible fields of the Air Referenced Velocity Report for the given Airborne Participant in accordance with §2.2.8.3.2 (all subparagraphs inclusive).

b. updates all possible fields of the Air Referenced Velocity Report to the Report Storage Buffer within 500 milliseconds of the receipt of the new message.

c. maintains the integrity of the Air Referenced Velocity Report for the given Airborne Participant in the Report Storage Buffer for 100 ±5 seconds, unless replaced by an updated Air Referenced Velocity Report.

2.4.10.4.1.3 Verification of the Report Assembly Track State Termination - Airborne Participant (§2.2.10.4.1.3)

Purpose/Introduction:

These test procedures verify that the Report Assembly Function properly terminates the Track State for an Airborne Participant as specified in §2.2.10.4.1.3.

Measurement Procedure:

Step 1: TYPE Equal ZERO – Altitude Data Available

For random Participants in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, induce Airborne Position Messages with the TYPE subfield set to ZERO, and with all 56 bits of the "ME" field set to ZEROs, except that the Barometric Altitude subfield is filled with valid data in accordance with §2.2.3.2.3.4.3.

Verify that for these Participants that the Report Assembly Function correctly updates the State Vector Report with the received Barometric Altitude. Verify that the Barometric Altitude Validity Flag, i.e., bit #3 of byte #4 of the State Vector Report was correctly set to ONE, indicating valid Altitude data.

Step 2: TYPE Equal ZERO – No Altitude Data Available

For random Participants in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, induce Airborne Position Messages with the TYPE subfield set to ZERO, and with all 56 bits of the "ME" field set to ZEROs.

Verify that for these Participants that the Report Assembly Function correctly discards the received Airborne Position Message and that no change is made to the State Vector Report as a result of the receipt of this Airborne Position Message with TYPE equal ZERO and all other "ME" field bits set to ZERO.

Step 3: Track State Termination

For each Participant in the Airborne scenario and simulation set up in Step 1 of §2.4.10.1.3 above, where you have verified that the Track State has been established, if no Airborne Position or Airborne Velocity Message has been received from the Participant for 25 ±5 seconds, then verify that for each Participant that the Track State is terminated by deleting all State Vector Reports, Mode Status Reports and ADS-B Target State Reports that were placed in the Report Output Storage Buffer for the given Participant.

Also verify that for this Participant that the Report Assembly Function correctly returns to the Acquisition State as specified in §2.2.10.3.1. Verify that the Report Mode Flag is set to "Acquisition" in the State Vector Report in accordance with the encoding specified in §2.2.8.1.22.

2.4.10.4.2 Verification of the Report Assembly Track State - Surface Participant (§2.2.10.4.2)

No specific test procedure is required to validate §2.2.10.4.2.

2.4.10.4.2.1 Verification of the Report Assembly Track State Initialization - Surface Participant (§2.2.10.4.2.1)

Purpose/Introduction:

These test procedures verify the proper initialization of the Track State for a given Surface Participant as established in accordance with §2.2.10.3.2, as well as the assembly of Mode Status Reports as specified in §2.2.10.4.2.1.

Measurement Procedure:

Step 1: Locally Unambiguous CPR Decode

a. For each test case in Table 2.4.10.4.2.1, provide the CPR Decoder function (see §A.1.7.6 of Appendix A) with the "***odd***" and "***even***" Surface Encodings within five (5) seconds of each other.

Table 2.4.10.4.2.1: Input Date for Local Unambiguous Surface Decode Zone Check

Input Data for Local Unambiguous Surface Decode Zone Checks											
	Angular Weighted Binary (AWB)Position of the Encoder in Degrees				Even Surface Encoding			Odd Surface Encoding			
Test Case	Latitude		Longitude		Lat.	Lon.	NL	Lat.	Lon.	NL	
	(Decimal)	(HEX)	(Decimal)	(HEX)	(HEX)	(HEX)	(Dec.)	(HEX)	(HEX)	(Dec.)	
1	-27.93897726	EC21DD4A	153.00998	6CCE9DE7	0BF7F	03636	53	15E70	0CFC1	53	

b. Verify that the CPR Decoder function (see §A.1.7.6 of Appendix A) provides an "***even***" and "***odd***" output **latitude** position within 0.00015 degrees of the **latitude** position indicated for the test case in Table 2.4.10.4.2.1.

c. Verify that the CPR Decoder function (see §A.1.7.6 of Appendix A) provides an "***even***" and "***odd***" output **longitude** position within 0.00015 degrees of the **longitude** position indicated for the test case in Table 2.4.10.4.2.1.

Step 2: Track State Initialization

a. Upon receipt of an "***even***" and "***odd***" encoded Surface Position Message from a given Surface Participant within a fifty (50) second period, verify that the Report Assembly Function correctly sets the Report Mode to "Track" in accordance with the formatting in §2.2.8.1.22.

b. Further verify that the Report Assembly Function initiates a complete review of all messages received for the given Surface Participant that have been placed in temporary storage in accordance with §2.2.10.1.3.

Upon completion of the review of all messages for the given Surface Participant, verify that the Report Assembly Function correctly structures all possible fields of the Mode Status Report for the given Surface Participant in accordance with §2.2.8.2 (all subsections inclusive).

c. Verify that the Mode Status Report is delivered to the Report Output Storage Buffer within 500 milliseconds of the receipt of the second half of that "***even/odd***" pair of Surface Position Messages that caused the initialization of the "Track" State for the given Surface Participant.

d. Verify that the integrity of the Mode Status Report is maintained for the given Surface Participant in the Report Output Storage Buffer for a period of 100 ±5 seconds, unless replaced by an updated Mode Status Report for that Participant.

2.4.10.4.2.2 Verification of the Report Assembly Track State Maintenance - Surface Participant (§2.2.10.4.2.2)

Purpose/Introduction:

These test procedures verify that the Track State is maintained for a given Surface Participant for as long as Surface Position Messages (see §2.2.3.2.4) are being received from the Surface Participant as specified in §2.2.10.4.2.2.

Measurement Procedure:

Step 1: Receipt of a new Surface Position Message

Verify that for each Surface Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified that the "Track" State has been established, and upon the receipt of a new Surface Position Message for the given Participant, verify that the Report Assembly Function correctly:

a. performs a locally unambiguous CPR decode of the Surface Participant position in accordance with §A.1.7.4 and §A.1.7.5 of Appendix A, and that the reasonableness test defined in §2.2.10.6.3 is performed and that the track is updated if the difference in the position decodes resulting from the reasonableness test are less than or equal to 0.75 NM if the last Position Message received was a Surface Position Message, or less than or equal 2.5 NM if the last Position Message received was an Airborne Position Message.

   However, if the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the reported position in the most recently received Position Message differs from the previously reported position by more than 0.75 NM, if the last Position Message received was a Surface Position Message, or more than 2.5 NM if the last Position Message received was an Airborne Position Message, then the most recently received position **is not** used to update the track.

b. updates all possible fields of the State Vector Report for the given Surface Participant in accordance with §2.2.8.1 (all subsections inclusive).

c. delivers the updated State Vector Report to the Report Output Storage Buffer within 500 milliseconds of the receipt of the new Surface Position Message for the given Participant.

d. maintains the integrity of the State Vector Report for the Surface Participant in the Report Output Storage Buffer for 100 ±5 seconds unless replace by an updated State Vector Report.

Step 2: Receipt of other Messages while in Track State and Creating a Mode Status

Verify that for each Surface Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified that the "Track" State has been established, and upon the receipt of a new Aircraft Identification and Category Message, Aircraft Operational Status Message, or Aircraft Status Message for the given Surface Participant, verify that the Report Assembly Function correctly:

a. updates all possible fields of the Mode Status Report for the given Surface Participant in accordance with §2.2.8.2 (all subsections inclusive).

b. delivers the updated Mode Status Report to the Report Output Storage Buffer within 500 milliseconds of the receipt of the new Message.

c. maintains the integrity of the Mode Status Report for the given Surface Participant in the Report Output Storage Buffer for 200 ±5 seconds unless replaced by an updated Mode Status Report.

2.4.10.4.2.3 Verification of the Report Assembly Track State Termination - Surface Participant (§2.2.10.4.2.3)

Purpose/Introduction:

This test procedure verifies that the Report Assembly Function properly terminates the Track State for a Surface participant as specified in §2.2.10.4.2.3.

Measurement Procedure:

For each Surface Participant in the Surface scenario and simulation set up in Step 2 of §2.4.10.1.3 above, where you have verified that the Track State has been established, if no Surface Position Message has been received from the Surface Participant for 225 ±5 seconds, then verify that for each Surface Participant that the Track State is terminated by deleting all State Vector Reports and Mode Status Reports that were placed into the Report Output Storage Buffer for the given Surface Participant.

Also verify that for this Participant that the Report Assembly Function correctly returns to the Acquisition State as specified in §2.2.10.3.2. Verify that the Report Mode Flag is set to "Acquisition" in the State Vector Report in accordance with the encoding specified in §2.2.8.1.22.

2.4.10.5 Verification of the Minimum Number of Participant Track Files (§2.2.10.5)

Purpose/Introduction

These test procedures verify that the ADS-B Receiving Subsystem is capable of maintaining a minimum number of track files as specified in Table 2-105 for a given equipage class, and is properly managing the ability to discard track files if capacity is exceeded, as specified in §2.2.10.5.

Measurement Procedure:

Step 1: Track File Scenario Selection and Initialization

Refer to Table 2-203, below, for information required in the following paragraphs. Select the Class of ADS-B Receiving Subsystem that is being tested from the far left column (0) of the table.

For the Class of ADS-B Receiving Subsystem selected, establish an Airborne scenario and simulation for the minimum number of participants shown in column 2 of the table. Select various altitudes, velocities, initial positions, and general directions for the participants such that all participants remain within the column 1 given range of the ADS-B receiving equipment under test. Maintain the same number of participants within the column 1 given range of the ADS-B receiving equipment under test for a duration of at least 20 minutes to ensure full execution of the test.

For the Class of ADS-B Receiving Subsystem selected, establish additional Airborne scenarios and simulations for the minimum number of participants shown in column 4 of the table. Select various altitudes, velocities, initial positions, and general directions for the participants such that all participants remain within the column 3 given range boundary from the ADS-B receiving equipment under test. Maintain the same number of participants within the column 3 given range boundary for at least 20 minutes to ensure full execution of the test.

Table 2-203: Participant Track File Stimulus Requirements

Column (0)	1	2	3	4
Equipage Class of ADS-B Receiving Subsystem	**Range (NM) for ADS-B Receiving Class**	**Number of Participant Track Files Within Range**	**Extended Range (NM) for ADS-B Receiving Class (min -to- max)**	**Number of Participant Track Files Within Extended Range**
A0	10	100	10 -to- 15	50
A1S and A1	20	200	20 -to- 30	100
A2	40	400	40 -to- 60	200
A3	60	400	60 -to- 90	200

Step 2: Track File Scenario Selection and Initialization

Initiate the simulation and verify that the ADS-B Report Generator function of the ADS-B Receiving Subsystem under test properly generates and delivers the appropriate State Vector, Mode Status, and Target State Reports for each Participant that is being tracked.

For the Class of ADS-B Receiving Subsystem under test, verify that the ADS-B Report Generator function maintains appropriate track files on the minimum number of participants provided in column 2 of Table 2-203. Regardless of the track file capacity of the ADS-B Receiving Subsystem under test, verify that any track files discarded are for participants at greater range than those retained.

2.4.10.6 Verification of Reasonableness Tests for CPR Decoding of Received Position Messages (§2.2.10.6)

2.4.10.6.1 Verification of Reasonableness Test Overview (§2.2.10.6.1)

No specific test procedure is required to validate §2.2.10.6.1.

2.4.10.6.2 Verification of Reasonableness Test Applied to Positions Determined from Globally Unambiguous CPR Decoding (§2.2.10.6.2)

Purpose/Introduction:

These test procedures verify that the proper validation is being performed to verify the Globally Unambiguous CPR decode established per §2.2.10.3.1, subparagraph "a" or §2.2.10.3.2, subparagraph "a," using the steps specified in §2.2.10.6.2.

Measurement Procedure:

Step 1: Airborne Target Setup

Set up the Test Generator to input to the receiver an Airborne Participant encoded using the following Messages to demonstrate proper position validation processing:

Test inputs:

Pair 1: A Position Message set consisting of first an "***even***" and then an "***odd***" Position Message, both encoded with the same NL value that produces a Globally Unambiguous CPR decode within the maximum operating range of the receiver, and both input to the receiver within 10 seconds of each other.

Pair 2: A Position Message set consisting of first an "***even***" and then an "***odd***" Position Message, both encoded with the same NL value but different than Pair 1 that produces a Globally Unambiguous CPR decode within the maximum operating range of the receiver, and both input to the receiver within 10 seconds of each other.

Along with the Position Messages, configure the target to output Airborne Velocity, Aircraft ID and Type Messages and Aircraft Operational Status Messages beginning at the same time the input of the Position Messages in the steps below and at the proper Airborne transmit rate.

Step 2: Verify Airborne Position Not Validated

Input a Pair 1 and verify that a State Vector Report is generated by the receipt of the "***odd***" Position Message of Pair 1. Input a Pair 2 and verify that no State Vector Report is output by the receipt of the "***odd***" Position Message or by the receipt of Airborne Velocity Messages after Pair 2.

Step 3: Verify Airborne Position Validated – Case 1

Input a Pair 1 and verify that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 1 is generated by the receipt of the "***odd***" Position Message of Pair 1. Input a Pair 2 and verify that no State Vector Report is output by the receipt of the "***odd***" Position Message. Repeat input of Pair 1 and verify that no State Vector Report is output by the receipt of the "***even***" Position Message and that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 1 is generated by the receipt of the "***odd***" Position Message. Repeat input of Pair 1 and verify that each Position and Velocity Message received results in a State Vector Report with position consistent with the Globally Unambiguous CPR position of Pair 1.

Step 4: Verify Airborne Position Validated – Case 2

Input a Pair 1 and verify that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 1 is generated by the receipt of the "***odd***" Position Message of Pair 1. Input a Pair 2 and verify that no State Vector Report is output by the receipt of the "***odd***" Position Message. Repeat input of Pair 2 and verify that no State Vector Report is output by the receipt of the "even" Position Message and that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 2 is generated by the receipt of the "***odd***" Position Message. Repeat input of Pair 2 and verify that each Position and Velocity Message received results in a State Vector Report with position consistent with the Globally Unambiguous CPR position of Pair 2.

Step 5: Surface Target Setup

Set up the Test Generator to input to the receiver a Surface Participant encoded using the following Messages to demonstrate proper position validation processing:

Test inputs:

Pair 1: A Position Message set consisting of first an "***even***" and then an "***odd***" Position Message, both encoded with the same NL value that produces a Globally Unambiguous CPR decode within the maximum operating range of the receiver, and both input to the receiver within 25 seconds of each other.

Pair 2: A Position Message set consisting of first an "***even***" and then an "***odd***" Position Message, both encoded with the same NL value but different than Pair 1 that produces a Globally Unambiguous CPR decode within the maximum operating range of the receiver, and both input to the receiver within 25 seconds of each other.

Along with the Position Messages, configure the target to output Aircraft ID and Type Messages and Aircraft Operational Status Messages beginning at the same time the input of the Position Messages in the steps below and at the proper Surface transmit rate.

Step 6: Verify Surface Position Not Validated

Input a Pair 1 and verify that a State Vector Report is generated by the receipt of the "***odd***" Position Message of Pair 1. Input a Pair 2 and verify that no State Vector Report is output by the receipt of the "***odd***" Position Message.

Step 7: Verify Surface Position Validated – Case 1

Input a Pair 1 and verify that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 1 is generated by the receipt of the "***odd***" Position Message of Pair 1. Input a Pair 2 and verify that no State Vector Report is output by the receipt of the "***odd***" Position Message. Repeat input of Pair 1 and verify that no State Vector Report is output by the receipt of the "even" Position Message and that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 1 is generated by the receipt of the "***odd***" Position Message. Repeat input of Pair 1 and verify that each Position Message received results in a State Vector Report with position consistent with the Globally Unambiguous CPR position of Pair 1.

Step 8: Verify Surface Position Validated – Case 2

Input a Pair 1 and verify that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 1 is generated by the receipt of the "***odd***" Position Message of Pair 1. Input a Pair 2 and verify that no State Vector Report is output by the receipt of the "***odd***" Position Message. Repeat input of Pair 2 and verify that no State Vector Report is output by the receipt of the "even" Position Message and that a State Vector Report consistent with the Globally Unambiguous CPR position of Pair 2 is generated by the receipt of the "***odd***" Position Message. Repeat input of Pair 2 and verify that each Position Message received results in a State Vector Report with position consistent with the Globally Unambiguous CPR position of Pair 2.

2.4.10.6.3 Verification of Reasonableness Test Applied to Positions Determined from Locally Unambiguous CPR Decoding (§2.2.10.6.3)

Purpose/Introduction:

These test procedures verify that the proper validation is being performed to verify the Locally Unambiguous CPR decode established per §2.2.10.4.1.2, subparagraph "a.(1)" for Airborne Participants, or §2.2.10.4.2.2, subparagraph "a.(1)" for Surface Participants, using the steps specified in §2.2.10.6.3.

Measurement Procedure:

Step 1: Airborne Target Setup

Set up the Test Generator to transmit an ADS-B Airborne Position Message with an “***even***” format containing the exact latitude and longitude data pair provided in the following table. Within 10 seconds, input another ADS-B Airborne Position Message with “***odd***” format containing the exact latitude and longitude data pair provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon
0	38.99836	-74	71361	65500		
1	38.99836	-74	98304	51301	38.998346	-74.000000

Verify that a Global CPR Decode has occurred and that the output of the ADS-B State Vector Report matches the corresponding values in the above table.

Input another ADS-B Airborne Position Message to the Receiving Subsystem with “***even***” format and data as provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon
0	39.0000	-74.0000	71361	65536	39.000000	-74.000025

Verify that the output of the ADS-B State Vector Report matches the corresponding values in the above table.

Step 2: Verification of Reasonableness Test with Distance Greater Than 6 NM

Input another ADS-B Airborne Position Message pair with “***even***” and “***odd***” formats containing the exact latitude and longitude data pair provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon	Delta Distance (NM)
0	39.099888	-73.998536	71386	67718	39.099884	-73.998533	6.004688
1	39.099888	-73.998536	98328	53482	39.099876	-73.998535	6.004220

Verify that the reception of either of the Position Messages does not produce updates to the established Participant Track nor the output of an ADS-B State Vector Report.

Step 3: Verification of Reasonableness Test with Distance Less Than 6 NM

Input an ADS-B Airborne Position Message pair with "***even***" and "***odd***" formats containing the exact latitude and longitude data pair provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon	Delta Distance (NM)
0	39.099788	-73.997803	71398	67716	39.099792	-73.997816	5.999666
1	39.099788	-73.997803	98340	53480	39.099783	-73.997803	5.999118

Verify that the reception of both of these Position Messages **does** produce updates to the established Participant Track and the output of an ADS-B State Vector Report matches the corresponding values in the table above.

Step 4: Verification of Reasonableness Test with Timing Test

Rerun the test procedure in Step 2 above using the same Latitude and Longitude values, but with a difference between the TOMRs of the previously received Position Message and the most recently received Position Message at a value greater than 30 seconds. Verify that the reception of each of these Position Messages does produce updates to the established Participant Track and the output of an ADS-B State Vector Report matches the corresponding values in the Step 2 table.

Step 5: Verification of Proper Timer Reset

Rerun the Airborne Target Setup as in Step 1 above. With the Global CPR Decode having been established, input an Airborne Position Message at what will become Time=0 with the parameters shown in the following table.

Injection Timing (seconds)	CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon	Delta Distance (NM)
0	0	39.099788	-73.997803	71398	67716	39.099792	-73.997816	5.999666
18	1	39.099888	-73.998536	98328	53482	39.099876	-73.998535	6.004220
40	0	39.099888	-73.998536	71386	67718	39.099884	-73.998533	6.004688

Verify that the reception of the initial Position Message at Time=0 **does** produce updates to the established Participant Track and that the output of the ADS-B State Vector Report matches the corresponding values in the above table.

Input an Airborne Position Message at Time=18 with the parameters shown in the above table. Verify that the reception of this Position Message **does not** produce updates to the established Participant Track, nor the output of an ADS-B State Vector Report.

Input an Airborne Position Message at Time=40 with the parameters shown in the above table. Verify that the reception of this Position Message **does** produce updates to the established Participant Track and that the output of the ADS-B State Vector Report matches the corresponding values in the above table.

Step 6: Surface Target Setup

Set up the Test Generator to transmit an ADS-B Surface Position Message with the "***even***" format containing the exact latitude and longitude data pair provided in the following table. Within 10 seconds, input another ADS-B Surface Position Message with "***odd***" format containing the exact latitude and longitude data pair provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon
0	38.99836	-74	23302	130929		
1	38.99836	-74	0	74133	38.998357	-74.000000

Verify that a Global CPR Decode has occurred and that the output of the ADS-B State Vector Report matches the corresponding values in the above table.

Input another ADS-B Surface Position Message to the Receiving Subsystem with "***even***" format and data as provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon
0	39.0000	-74.0000	23302	0	39.000000	-73.999995

Verify that the output of the ADS-B State Vector Report matches the corresponding values in the above table.

Step 7: Verification of Reasonableness Test with Distance Greater Than 0.75 NM

Input an ADS-B Airborne Position Message pair with "***even***" and "***odd***" formats containing the exact latitude and longitude data pair provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon	Delta Distance (NM)
0	39.061486	-73.99817	23424	5373	39.061489	-73.998174	3.697247
1	39.061486	-73.99817	120	79557	39.061482	-73.998169	3.696844

Verify that the reception of either of these Position Messages **does not** produce updates to the established Participant Track nor the output of an ADS-B State Vector Report.

Step 8: Verification of Reasonableness Test with Distance Less Than 0.75 NM

Input an ADS-B Surface Position Message pair with "even" and "odd" formats containing the exact latitude and longitude data pair provided in the following table.

CPR Format	Lat	Lon	XZ	YZ	Decoded Lat	Decoded Lon	Delta Distance (NM)
0	39.01028	-73.99817	23424	898	39.010277	-73.998174	0.623613
1	39.01028	-73.99817	120	75157	39.010275	-73.998169	0.623531

Verify that each of these Position Messages **does** produce updates to the established Participant Track and the output of an ADS-B State Vector Report matches the corresponding values in the table above.

Step 9: Verification of Reasonableness Test with Timing Test

Rerun the test procedure in Step 7 above using the same Latitude and Longitude values, but with a difference between the TOMRs of the previously received Position Message and the most recently received Position Message at a value greater than 30 seconds. Verify that the reception of each of these Position Messages **does** produce updates to the established Participant Track and the output of an ADS-B State Vector Report matches the corresponding values in the Step 7 table.

2.4.11 Verification of Self Test and Monitors (§2.2.11)

No specific test procedure is required to validate §2.2.11.

2.4.11.1 Verification of Self Test (§2.2.11.1)

Purpose/Introduction:

These test procedures verify that self test transmissions from ADS-B Transmitting Subsystem comply with the requirements of §2.2.11.1.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a Wide Band Dual Channel Oscilloscope (HP 1710, or equivalent). Provide a method of detecting and monitoring ADS-B broadcast messages.

Measurement Procedure:

Load valid data into the ADS-B Airborne Position format and ensure that the expected ADS-B transmissions occur. Monitor all ADS-B broadcast messages for the occurrence of a “TYPE” Code = “23.”

Measure the single pulse in the “TYPE” Code = “23” message that has the highest RF power and verify that the power does not exceed -40 dBm. Verify that the average rate of the “TYPE” Code = “23” messages does not exceed one in a 10 second interval.

2.4.11.2 Verification of Broadcast Monitoring (§2.2.11.2)

No specific test procedure is required to validate §2.2.11.2.

2.4.11.2.1 Verification of Transponder-Based Equipment Broadcast Monitoring (§2.2.11.2.1)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting Subsystem properly enunciates the “Fail/Warn” state if DF=17 transmissions do not occur at the rates specified in §2.2.3.3 through §2.2.3.3.2.10.

In order to not induce unnecessary intermittent Fail/Warn declarations, the squitter monitor **shall** implement appropriate “debounce” and recovery techniques provided for in Table 2-2.4.11.2.1. In these regards, “debounce” refers to the number of successive maximum transmit intervals that a particular squitter message can be missed (e.g., not transmitted) plus an additional time of 100 milliseconds to process and activate the Fail/Warn mechanism. Likewise, “recovery” refers to the number of successive maximum transmit intervals within which a particular squitter message must be transmitted plus 100 milliseconds to process and de-activate the Fail/Warn mechanism.

Table 2-2.4.11.2.1: Extended Squitter Monitor Time Allocation

1090ES Message Type	Transmit Interval (seconds)	Maximum Time to Declare Fail/Warn (seconds)	Number of Intervals to Declare Fail/Warn	Maximum Time to Clear Fail/Warn (seconds)	Number of Intervals to Clear Fail/Warn
Airborne Position	0.4 to 0.6	1.9	2	1.9	3
Airborne Velocity	0.4 to 0.6	1.9	2	1.9	3
Aircraft Identification and Category	4.8 to 5.2	15.7	3	5.3	1
Aircraft Identification and Category	9.8 to 10.2	30.7	3	10.3	1
Surface Position	0.4 to 0.6	1.9	2	1.9	3
Surface Position	4.8 to 5.2	15.7	3	5.3	1
Target State and Status	1.2 to 1.3	5.3	4	4.0	3
Aircraft Operational Status	0.7 to 0.9	1.9	2	1.9	2
Aircraft Operational Status	2.4 to 2.6	5.3	2	2.7	1
Aircraft Operational Status	4.8 to 5.2	10.5	2	5.3	1
Extended Squitter Aircraft Status	0.7 to 0.9	1.9	2	1.9	2
Extended Squitter Aircraft Status	2.4 to 2.6	5.3	2	2.7	1

Notes:

1. *All Maximum Time to Declare Fail/Warn (column 3) conditions are based on the maximum transmit interval (column 2) multiplied by the Number of Intervals to Declare Fail/Warn (column 4) plus an additional processing time of 100 milliseconds.*
2. *All Maximum Time to Clear Fail/Warn (column 5) conditions are based on the maximum Transmit Interval (column 2) multiplied by the Number of Intervals to Clear Fail/Warn (column 6) plus an additional processing time of 100 milliseconds.*

➔ No test procedures are currently provided in 2.4.11.2.1 to address the line items above that are highlighted in Aqua. ➔

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting and monitoring ADS-B broadcast messages. Provide a method of modifying the transmission rates of DF=17 transmitted messages such that the rates do not comply with the rates specified in §2.2.3.3 through §2.2.3.3.2.10.

Note: *The test procedures provided in the following subparagraphs require the capability to vary the rate of ADS-B transmitted messages. It **shall** be acceptable for the manufacturer to demonstrate compliance to the following procedures by software verification.*

Measurement Procedure:

The following procedures **shall** be performed in the absence of other major operations being performed by the ADS-B Transmitting Subsystem. Specifically, if the ADS-B Transmitting Subsystem is a subset of the Mode-S transponder, then all interrogations of the transponder **shall** be terminated during the performance of the following tests.

Step 1: Minimum DF=17 transmissions for Airborne Participants

a. Provide the ADS-B transmitting monitoring function with all necessary information to enable the transmitting function to generate the following DF=17 transmitted messages:

(1). Airborne Position Messages (§2.2.3.2.3),

(2). Aircraft Identification and Category Messages (§2.2.3.2.5), and

(3). Airborne Velocity Messages (§2.2.3.2.6)

Verify that the ADS-B transmitting monitoring function properly transmits Airborne Position, Aircraft Identification and Category, and Airborne Velocity Messages at the rates required in §2.2.3.3.2.2, §2.2.3.3.2.4, and §2.2.3.3.2.5.

Verify that the ADS-B transmitting monitoring function does not enunciate any "Fail Warn" conditions.

b. Decrease the transmission rate of the Airborne Position Message below the acceptable rate provided in §2.2.3.3.2.2. Verify that the ADS-B transmission monitoring function properly enunciates the "Fail Warn" state within no more than 1.9 seconds.

Note: *The time chosen is based on 3 times the accepted maximum time of 0.6 second with an allowance of an additional 100 milliseconds.*

c. Increase the transmission rate of the Airborne Position Message to comply with the rates specified in §2.2.3.3.2.2. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 1.9 seconds after returning the rate to the acceptable rate.

d. Increase the transmission rate of the Airborne Position Message such that it exceeds the acceptable rate provided in §2.2.3.3.2.2. Verify that the ADS-B transmission monitoring function properly enunciates the "Fail Warn" state within 1.9 seconds.

e. Decrease the transmission rate of the Airborne Position Message to comply with the rates specified in §2.2.3.3.2.2. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 1.9 seconds after returning the rate to the acceptable rate.

f. Decrease the transmission rate of the Aircraft Identification and Category Messages below the acceptable rate provided in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function properly enunciates the "Fail Warn" state within 15.7 seconds.

g. Increase the transmission rate of the Aircraft Identification and Category Messages to comply with the rates specified in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 5.3 seconds after returning the rate to the acceptable rate.

h. Increase the transmission rate of the Aircraft Identification and Category Messages such that it exceeds the acceptable rate provided in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function properly enunciates the “Fail Warn” state within 15.7 seconds.

i. Decrease the transmission rate of the Aircraft Identification and Category Message to comply with the rates specified in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function does not enunciate any “Fail Warn” conditions within 5.3 seconds after returning the rate to the acceptable rate.

j. Repeat steps b through e for Airborne Velocity Messages using the rates specified in §2.2.3.3.2.5.

k. Set the rates of all three messages, e.g., Airborne Position, Aircraft Identification and Category, and Airborne Velocity Messages, such that the rates exceed those specified in §2.2.3.3.2.2, §2.2.3.3.2.4, and §2.2.3.3.2.5 respectively.

l. Verify that the ADS-B transmitting monitoring function properly enunciates the “Fail Warn” state within no more than 1.9 seconds.

m. Set the rates of all three messages, e.g., Airborne Position, Aircraft Identification and Category, and Airborne Velocity Messages, to the rates specified in §2.2.3.3.2.2, §2.2.3.3.2.4, and §2.2.3.3.2.5 respectively.

   Verify that the ADS-B transmission monitoring function does not enunciate any “Fail Warn” conditions within 5.3 seconds after returning the rates to the acceptable rates.

Step 2: Minimum DF=17 transmissions for Surface Participants

a. Provide the ADS-B transmitting monitoring function with all necessary information to enable the transmitting function to generate the following DF=17 transmitted messages:

   (1). Surface Position Messages (§2.2.3.2.3),

   (2). Aircraft Identification and Category Messages (§2.2.3.2.4), and

   Establish sufficient Ground Speed Data to the ADS-B transmitting monitoring function to establish the high rate for Surface Position and Aircraft Identification and Category messages.

   Verify that the ADS-B transmitting monitoring function properly transmits Surface Position and Aircraft Identification and Category Messages at the rates required in §2.2.3.3.2.3 and §2.2.3.3.2.4 respectively.

b. Decrease the transmission rate of the Surface Position Message below the acceptable high rate provided in §2.2.3.3.2.3. Verify that the ADS-B transmission monitoring function properly enunciates the “Fail Warn” state within no more than 1.9 seconds.

c. Increase the transmission rate of the Surface Position Message to comply with the high rates specified in §2.2.3.3.2.3. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 1.9 seconds after returning the rate to the acceptable rate.

d. Increase the transmission rate of the Surface Position Message such that it exceeds the acceptable high rate provided in §2.2.3.3.2.3. Verify that the ADS-B transmission monitoring function properly enunciates the "Fail Warn" state within 1.9 seconds.

e. Decrease the transmission rate of the Surface Position Message to comply with the high rates specified in §2.2.3.3.2.3. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 1.9 seconds after returning the rate to the acceptable rate.

f. Decrease the transmission rate of the Aircraft Identification and Category Messages below the acceptable high rate provided in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function properly enunciates the "Fail Warn" state within 15.7 seconds.

g. Increase the transmission rate of the Aircraft Identification and Category Messages to comply with the high rates specified in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 5.3 seconds after returning the rate to the acceptable rate.

h. Increase the transmission rate of the Aircraft Identification and Category Messages such that it exceeds the acceptable high rate provided in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function properly enunciates the "Fail Warn" state within 15.7 seconds.

i. Decrease the transmission rate of the Aircraft Identification and Category Message to comply with the high rates specified in §2.2.3.3.2.4. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 5.3 seconds after returning the rate to the acceptable rate.

j. Set the rates of both messages, e.g., Surface Position and Aircraft Identification and Category Messages, such that the rates exceed the high rates those in §2.2.3.3.2.3 and §2.2.3.3.2.4, respectively. Verify that the ADS-B transmitting monitoring function properly enunciates the "Fail Warn" state within no more than 1.9 seconds.

k. Set the rates of both messages, e.g., Surface Position and Aircraft Identification and Category Messages, to the high rates specified in §2.2.3.3.2.3 and §2.2.3.3.2.4, respectively. Verify that the ADS-B transmission monitoring function does not enunciate any "Fail Warn" conditions within 5.3 seconds after returning the rates to the acceptable rates.

l. Decrease Ground Speed Data to the ADS-B transmitting monitoring function to establish the low rate for Surface Position and Aircraft Identification and Category Messages. Verify that the ADS-B transmitting monitoring function properly transmits Surface Position and Aircraft Identification and Category Messages at the low rates required in §2.2.3.3.2.3 and §2.2.3.3.2.4, respectively.

m. Repeat steps b through e for Surface Position Messages using the low rates specified in §2.2.3.3.2.3 and applying the following exceptions:

(1). The response time to set the "Fail Warn" state **shall** not exceed 15.7 seconds in steps b and d.

(2). The response time to clear the "Fail Warn" state **shall** not exceed 5.3 seconds in steps c and e.

n. Repeat steps f through i for Aircraft Identification and Category Messages using the low rates specified in §2.2.3.3.2.4 and applying the following exceptions:

(1). The response time to set the "Fail Warn" state **shall** not exceed 30.7 seconds in steps f and h.

(2). The response time to clear the "Fail Warn" state **shall** not exceed 10.3 seconds in steps c and e.

Step 3: Maximum DF=17 transmissions for Airborne Participants

a. Provide the ADS-B transmitting monitoring function with all necessary information to enable the transmitting function to generate the following DF=17 transmitted messages:

(1). Airborne Position Messages (§2.2.3.2.3),

(2). Aircraft Identification and Category Messages (§2.2.3.2.5), and

(3). Airborne Velocity Messages (§2.2.3.2.6)

(4). Target State and Status Messages (§2.2.3.2.7.1)

(5). Aircraft Operational Status Messages (§2.2.3.2.7.2)

(6). Extended Squitter Aircraft Status Messages (TYPE=28) (§2.2.3.2.7.8)

Verify that the ADS-B transmitting monitoring function properly transmits Airborne Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status, Aircraft Operational Status, and Extended Squitter Aircraft Status Messages at the rates required in §2.2.3.3.2.2, §2.2.3.3.2.4, §2.2.3.3.2.5, §2.2.3.3.2.6.1, §2.2.3.3.2.6.2, and §2.2.3.3.2.6.3 respectively.

Verify that the ADS-B transmission monitor function does not enunciate any "Fail Warn" conditions.

b. Decrease the transmission rate of the Target State and Status Messages below the acceptable rate provided in §2.2.3.3.2.6.1. Verify that the ADS-B transmission monitor function properly enunciates the “Fail Warn” state in no more than 5.3 seconds.

c. Increase the transmission rate of the Target State and Status Messages to comply with the rates specified in §2.2.3.3.2.6.1. Verify that the ADS-B transmission monitor function does not enunciate any “Fail Warn” conditions 4.0 seconds after returning the rate to the acceptable rate.

d. Increase the transmission rate of the Target State and Status Messages such that it exceeds the acceptable rate provided in §2.2.3.3.2.6.1. Verify that the ADS-B transmission monitor function properly enunciates the “Fail Warn” state in 5.3 seconds.

e. Decrease the transmission rate of the Target State and Status Messages to comply with the rates specified in §2.2.3.3.2.6.1. Verify that the ADS-B transmission monitor function does not enunciate any “Fail Warn” conditions 3.9 seconds after returning the rate to the acceptable rate.

f. Decrease the transmission rate of the Aircraft Operational Status Messages below the acceptable rate provided in §2.2.3.3.2.6.2. Verify that the ADS-B transmission monitor function properly enunciates the “Fail Warn” state in no more than 5.3 seconds.

g. Increase the transmission rate of the Aircraft Operational Status Messages to comply with the rates specified in §2.2.3.3.2.6.2. Verify that the ADS-B transmission monitor function does not enunciate any “Fail Warn” conditions 2.7 seconds after returning the rate to the acceptable rate.

h. Increase the transmission rate of the Aircraft Operational Status Messages such that it exceeds the acceptable rate provided in §2.2.3.3.2.6.2. Verify that the ADS-B transmission monitor function properly enunciates the “Fail Warn” state in 5.3 seconds.

i. Decrease the transmission rate of the Aircraft Operational Status Messages to comply with the rates specified in §2.2.3.3.2.6.2. Verify that the ADS-B transmission monitor function does not enunciate any “Fail Warn” conditions 3.7 seconds after returning the rate to the acceptable rate.

j. Decrease the transmission rate of the Extended Squitter Aircraft Status Messages below the acceptable rate provided in §2.2.3.3.2.6.3. Verify that the ADS-B transmission monitor function properly enunciates the “Fail Warn” state in no more than 5.3 seconds.

k. Increase the transmission rate of the Extended Squitter Aircraft Status Messages to comply with the rates specified in §2.2.3.3.2.6.3. Verify that the ADS-B transmission monitor function does not enunciate any “Fail Warn” conditions 2.7 seconds after returning the rate to the acceptable rate.

l. Increase the transmission rate of the Extended Squitter Aircraft Status Messages such that it exceeds the acceptable rate provided in §2.2.3.3.2.6.3. Verify that the ADS-B transmission monitor function properly enunciates the "Fail Warn" state in no more than 5.3 seconds.

m. Decrease the transmission rate of the Extended Squitter Aircraft Status Messages to comply with the rates specified in §2.2.3.3.2.6.3. Verify that the ADS-B transmission monitor function does not enunciate any "Fail Warn" conditions 2.7 seconds after returning the rate to the acceptable rate.

2.4.11.2.2 Verification of Non-Transponder-Based Equipment Broadcast Monitoring (§2.2.11.2.2)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting monitor function properly enunciates the "Fail Warn" state if DF=18 transmissions do not occur at the rates specified in §2.2.3.3 through §2.2.3.3.2.10.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting and monitoring ADS-B broadcast messages. Provide a method of modifying the transmission rates of DF=18 transmitted messages such that the rates do not comply with the rates specified in §2.2.3.3 through §2.2.3.3.2.10.

Note: *The test procedures provided in the following subparagraphs require the capability to vary the rate of ADS-B transmitted messages. It is explicitly intended that the equipment manufacturer provide the means to accomplish this task under closed Unit conditions.*

Measurement Procedure:

The following procedures **shall** be performed in the absence of other major operations being performed by the ADS-B transmitting monitoring function.

Repeat all of the procedures provided in §2.4.11.2.1 with the exception that all broadcast messages use DF=18 instead of DF=17.

2.4.11.3 Verification of Address (§2.2.11.3)

No specific test procedure is required to validate §2.2.11.3.

2.4.11.3.1 Verification of Transponder-Based Equipment Addressing (§2.2.11.3.1)

Transponder-Based Equipment **shall** be tested in accordance with the procedures provided in §2.4.11.3.2.

Note: *The requirement to test Transponder-Based equipment is provided herein due to the fact that the test requirements provided in RTCA DO-181D do not test the function adequately. ➔ XXXXXX TBD XXXXXX DO WE STILL WANT TO SAY THIS ? ➔*

2.4.11.3.2 Verification of Non-Transponder-Based Equipment Addressing (§2.2.11.3.2)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting monitor function properly enunciates the "Fail Warn" condition in the event that the ICAO 24-Bit Address (§2.2.5.1.1) provided to the ADS-B Transmitting Subsystem is set to ALL ZEROs or ALL ONEs.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of detecting and monitoring ADS-B broadcast messages. Provide a method of modifying the ICAO 24-Bit Address provided to the Unit Under Test (UUT).

Measurement Procedure:

Step 1: Initial Conditions

Establish any state where the ADS-B Transmission Function is operational and indicating no Fail Warn conditions.

Step 2: Address set to ALL ZEROs

Remove power from the UUT. Set the ICAO 24-Bit Address provided to the UUT to ALL ZEROs. Apply power to the UUT. Verify that the ADS-B transmission function properly enunciates the "Fail Warn" state within no more than 2.0 seconds.

Step 3: New Initial Conditions

Repeat Step 1.

Step 4: Address set to ALL ONE's

Remove power from the UUT. Set the ICAO 24-Bit Address provided to the UUT to ALL ONE's. Apply power to the UUT. Verify that the ADS-B transmission function properly enunciates the "Fail Warn" state within no more than 2.0 seconds.

Step 5: Restore Normal Operations

Establish any state where the ADS-B Transmission Function is operational and indicating no Fail Warn conditions prior to continuing with further testing.

2.4.11.4 Verification of Receiver Self Test Capability (§2.2.11.4)

Purpose/Introduction:

The purpose of this test procedure is to verify that the ADS-B Receiving Devices provide sufficient self-test capability to detect a loss of capability to receive ADS-B Messages, structure appropriate ADS-B reports, and make such reports available to the intended user interface. The procedure also verifies that should the receiving device detect that these basic functions cannot be performed properly, then the receiving device properly sets the appropriate "Fail/Warn" indicators to the "Fail/Warn" state.

Equipment Required:

Provide a method of supplying the Receiving function under test with ADS-B Broadcast Messages to include Airborne Position, Airborne Velocity, and Aircraft Identification and Category Messages as a minimum. Provide a method of receiving and storing all Output Messages or Reports generated by the receiving function under test. Provide a method of analyzing the Output Messages or Reports generated by the receiving function under test. Provide a method of inducing a fault condition into the Receiving function such that it can no longer properly receive and process ADS-B Broadcast Messages.

Note: *The manufacturer must provide a method of inducing or simulating failure of the ADS-B Broadcast Message reception capability. This may be done by appropriate Software Test provisions or may require that the unit under test be opened in order to provide access to internal circuitry.*

Measurement Procedure:

Step 1: Establish ADS-B Broadcast Message Stimulus

Configure the ADS-B Broadcast Message simulation function to provide the ADS-B Receiving Subsystem under test with Airborne Position, Airborne Velocity, and Aircraft Identification and Category Messages for at least 10 Airborne participants. Each message **shall** be provided at the rates specified in §2.2.3.3.

Verify that the Receiving function under test is generating the appropriate Reports that are expected for the ADS-B Broadcast Messages being provided by the simulation function.

Step 2: Induce Receiver Failure

Induce a failure into the ADS-B Receiving Subsystem under test such that ADS-B Broadcast Messages can no longer be received.

Verify that the ADS-B Receiving Subsystem properly enunciates the "Fail Warn" state for as long as the failure is induced.

Step 3: Remove Induced Receiver Failure

Remove the induced failure and allow the ADS-B Receiving Subsystem under test to return to normal operation.

Verify that the ADS-B Receiving Subsystem does not enunciate the "Fail Warn" state 2.0 seconds after removing the induced failure.

2.4.11.5 Verification of Failure Annunciation (§2.2.11.5)

No specific test procedure is required to validate §2.2.11.5.

2.4.11.5.1 Verification of ADS-B Transmission Device Failure Annunciation (§2.2.11.5.1)

Appropriate test procedures to validate §2.2.11.5.1 are provided in §2.4.11.2.1 through §2.4.11.3.2.

2.4.11.5.2 Verification of ADS-B Receiving Device Failure Annunciation (§2.2.11.5.2)

Appropriate test procedures to validate §2.2.11.5.2 are provided in §2.4.11.4.

2.4.11.5.3 Verification of Co-Located ADS-B Transmission and Receiving Device Failure Annunciation (§2.2.11.6)

Appropriate test procedures to validate §2.2.11.5.1 are provided in §2.4.11.2.1 through §2.4.11.3.2, and §2.4.11.4.

2.4.12 Verification of Response to Mutual Suppression Pulses (§2.2.12)

No specific test procedure is required to validate §2.2.12.

2.4.12.1 Verification of ADS-B Transmitting Subsystem Response to Mutual Suppression Pulses (§2.2.12.1)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting Subsystem functions properly in the Mutual Suppression environment as specified in §2.2.12.1.

Equipment Required:

Provide a method of loading valid data for ADS-B broadcast messages into the ADS-B equipment under test. Provide a method of supplying the ADS-B Transmitting Subsystem with Mutual Suppression Pulses. Provide a method of monitoring and recording ADS-B transmissions and the time at which such transmissions are generated with respect to the end of a mutual suppression pulse.

Measurement Procedure:

Step 1: Initialize ADS-B Airborne Participant Transmissions

Provide the ADS-B Transmitting Subsystem with all necessary information to enable the transmitting function to generate the following DF=17 transmitted messages:

(1). Airborne Position Messages (§2.2.3.2.3),

(2). Aircraft Identification and Category Messages (§2.2.3.2.5), and

(3). Airborne Velocity Messages (§2.2.3.2.6)

Verify that the ADS-B Transmitting Subsystem properly transmits Airborne Position, Aircraft Identification and Category, and Airborne Velocity Messages at the rates required in §2.2.3.3.2.2, §2.2.3.3.2.4, and §2.2.3.3.2.5.

Step 2: Apply Mutual Suppression

Apply Mutual Suppression pulses of the maximum length that the suppression interface is designed to accept. Verify that no ADS-B transmissions occur during the suppression period.

Record the transmissions that are generated and verify that transmissions can be output no later than 15 microseconds after the end of the mutual suppression pulse.

2.4.12.2 Verification of ADS-B Receiving Device Response to Mutual Suppression Pulses (§2.2.12.2)

Purpose/Introduction:

These test procedures verify that the ADS-B Receiving device functions properly in the Mutual Suppression environment as specified in §2.2.12.2.

Equipment Required:

Provide a method of supplying ADS-B Transmitted messages to the ADS-B Receiving Subsystem. Provide a method of supplying the ADS-B Receiving Subsystem with Mutual Suppression Pulses that can be synchronized to the ADS-B Transmitted messages provided to the ADS-B Receiving Subsystem. Provide a method of monitoring and recording the Receiving function decoded ADS-B Messages or structured ADS-B Reports.

Measurement Procedure:

Step 1: Initialize ADS-B Message Reception

Provide the ADS-B Receiving Subsystem with appropriate ADS-B Messages at a minimum rate of two per second and having a signal level of the Receiver MTL +3 dB. Verify that the Receiving function decodes at least 99 percent of the messages provided to the receiver.

Step 2: Apply Mutual Suppression

a. Apply Mutual Suppression pulses synchronized to start before each ADS-B Message provided to the Receiving function.

   Ensure that the duration of each Mutual Suppression pulse exceeds that of the ADS-B Messages being provided to the Receiving function. Verify that no ADS-B Messages are successfully decoded by the Receiving function.

b. Apply Mutual Suppression pulses that do not over lap any of the ADS-B Messages provided to the Receiving function and are synchronized to finish 15 microseconds prior to the start of each ADS-B Message provided to the Receiving function.

   Verify that at least 90 percent of the ADS-B Messages provided to the Receiving function are properly decoded by the Receiving function.

2.4.13 Verification of Antenna System (§2.2.13)

No specific test procedure is required to validate §2.2.13.

2.4.13.1 Verification of Transmit Pattern Gain (§2.2.13.1)

Appropriate installed equipment test procedures to verify the Transmit Pattern Gain are provided in §3.3.4.6.1.

2.4.13.2 Verification of Receiver Pattern Gain (§2.2.13.2)

Appropriate installed equipment test procedures to verify the Receiver Pattern Gain are provided in §3.3.4.6.2.

2.4.13.3 Verification of Frequency Requirements for Transmit and Receive Antenna(s) (§2.2.13.3)

Appropriate installed equipment test procedures to verify the Frequency Requirements are provided in §3.3.4.6.3.

2.4.13.4 Verification of Impedance and VSWR (§2.2.13.4)

Appropriate installed equipment test procedures to verify the Impedance and VSWR are provided in §3.3.4.6.4.

2.4.13.5 Verification of Polarization (§2.2.13.5)

Appropriate installed equipment test procedures to verify the Polarization are provided in §3.3.4.6.5.

2.4.13.6 Verification of Diversity Operation (§2.2.13.6)

No specific test procedure is required to validate §2.2.13.6.

2.4.13.6.1 Verification of Transmitting Diversity (§2.2.13.6.1)

Purpose/Introduction:

This test procedure verifies that an ADS-B Transmitting Subsystem implements transmitting diversity properly by transmitting each required type of ADS-B Message alternately from the top and bottom antenna channels as specified in §2.2.13.6.1.

Equipment Required:

Provide a method of supplying the ADS-B Transmitting Subsystem with all data necessary to structure ADS-B Airborne Position, Airborne Velocity, and Aircraft Identification and Category Messages. All data **shall** be provided via the operational interfaces. Provide a method of monitoring the ADS-B Broadcast Messages transmitted by the ADS-B Transmitting Subsystem.

Measurement Procedure:

Step 1: Broadcast Message Initialization

Provide the ADS-B Transmitting Subsystem with all data necessary to structure Airborne Position, Airborne Velocity, and Aircraft Identification and Category ADS-B Broadcast Messages.

Step 2: Broadcast Message Verification

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Airborne Position Messages alternately on the Top and Bottom RF ports.

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Airborne Velocity Messages alternately on the Top and Bottom RF ports.

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Aircraft Identification and Category Messages alternately on the Top and Bottom RF ports.

2.4.13.6.1.1 Verification of Transmitting Diversity Channel Isolation (§2.2.13.6.1.1)

Purpose/Introduction:

This test procedure verifies that the peak RF power transmitted from the selected antenna exceeds the power transmitted from the non-selected antenna by at least 20 dB as specified in §2.2.13.6.1.1.

Equipment Required:

Provide a method of supplying the ADS-B Transmitting Subsystem with all data necessary to structure ADS-B Airborne Position Broadcast messages. All data **shall** be provided via the operational interfaces. Provide a method of detecting the RF pulses of the ADS-B Broadcast Message for display on an oscilloscope. Provide a Wide Band Dual Channel Oscilloscope (HP 1710B, or equivalent).

Measurement Procedure:

Step 1: Broadcast Message Initialization

Provide the ADS-B Transmitting Subsystem with all data necessary to structure Airborne Position Type ADS-B Broadcast Messages.

Step 2: Broadcast Message Verification

Verify that the ADS-B Transmitting Subsystem properly transmits the appropriate Airborne Position Messages alternately on the Top and Bottom RF ports.

Step 3: Bottom Channel Isolation Verification

During the time that the Airborne Position Message is actually being transmitted via the Top Channel RF Port, verify that the signal level of any transmission on the Bottom Channel RF Port is at least 20 dB below the signal level of the transmission on the Top Channel RF Port.

Step 4: Top Channel Isolation Verification

During the time that the Airborne Position Message is actually being transmitted via the Bottom Channel RF Port, verify that the signal level of any transmission on the Top Channel RF Port is at least 20 dB below the signal level of the transmission on the bottom Channel RF Port.

2.4.13.6.2 Verification of Receiving Diversity (§2.2.13.6.2)

Appropriate test procedures to verify the performance of §2.2.13.6.2 are provided in §2.4.13.6.2.1 through §2.4.13.6.2.2.

2.4.13.6.2.1 Verification of Full Receiver and Message Processing or Receiver Switching Front-End Diversity (§2.2.13.6.2)

Purpose/Introduction:

This test procedure verifies that the ADS-B Receiving Subsystem properly implements diversity by demonstrating proper reception of ADS-B Broadcast Messages from either the top antenna, or the bottom antenna, or both antennas. This procedure applies to those configurations that implement Full receiver and message processing function diversity as discussed in §2.2.13.6.2.a. This procedure also apples to those configurations that implement Receiver Switching Front-End diversity as discussed in §2.2.13.6.2.b.

Equipment Required:

Provide a method of supplying the equipment under test with appropriate ADS-B Airborne Position Messages. Provide a method of monitoring the Output Messages and/or ADS-B Reports generated by the ADS-B Receiving Subsystem. Provide an RF Splitter/Combiner (2 port, or 3 dB type). Provide an RF Attenuators (Fixed, various attenuation values, as needed).

Measurement Procedure:

Step 1: Test Equipment Configuration

Connect the ADS-B Broadcast Message generator to the RF Splitter input. Connect each output from the RF Splitter to the input of an RF Attenuator. Connect the output of one RF Attenuator to the Top Channel RF input port of the equipment under test. Connect the output of the other RF Attenuator to the Bottom Channel RF input port of the equipment under test.

Step 2: Top Channel is Primary Receiver

Adjust the Top Channel attenuator such that the signal level provided to the Top Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Adjust the Bottom Channel attenuator such that the signal level provided to the Bottom Channel RF input port is 20 dB less than the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 90% of the Airborne Position Messages provided to the Top Channel RF input port.

Step 3: Bottom Channel is Primary Receiver

Adjust the Bottom Channel attenuator such that the signal level provided to the Bottom Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Adjust the Top Channel attenuator such that the signal level provided to the Top Channel RF input port is 20 dB less than the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 90% of the Airborne Position Messages provided to the Bottom Channel RF input port.

Step 4: Top / Bottom Channel Equivalent

Adjust the Bottom Channel attenuator such that the signal level provided to the Bottom Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Adjust the Top Channel attenuator such that the signal level provided to the Top Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for between 90% and 100% of the Airborne Position Messages provided to the Bottom Channel RF input port.

2.4.13.6.2.2 Verification Receiving Antenna Switching Diversity (§2.2.13.6.2)

Purpose/Introduction:

This test procedure verifies that the ADS-B Receiving Subsystem properly implements diversity by demonstrating proper reception of ADS-B Broadcast Messages from either the top antenna or the bottom antenna. This procedure applies to those configurations that implement Receiving Antenna switching as discussed in §2.2.13.6.2.c.

Equipment Required:

Provide a method of supplying the equipment under test with appropriate Airborne Position ADS-B Broadcast Messages. Provide a method of monitoring the Output Messages and/or ADS-B Reports generated by the ADS-B Receiving Subsystem. Provide RF Attenuators (Fixed, various attenuation values, as needed).

Measurement Procedure:

Step 1: Top Channel is Primary Receiver

Connect the ADS-B Broadcast Message generator to the RF Attenuator input. Connect the output of the RF Attenuator to the Top Channel RF input port of the equipment under test.

Adjust the attenuator such that the signal level provided to the Top Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 45% of the Airborne Position Messages provided to the Top Channel RF input port.

Step 2: Bottom Channel is Primary Receiver

Connect the ADS-B Broadcast Message generator to the RF Attenuator input. Connect the output of the RF Attenuator to the Bottom Channel RF input port of the equipment under test.

Adjust the attenuator such that the signal level provided to the Bottom Channel RF input port is at least 3 dB above the MTL of the equipment under test.

Configure the ADS-B Broadcast Message generator to provide only Airborne Position Messages for a single participant with the position continuously changing in the message.

Verify that the ADS-B Receiving Subsystem generates appropriate Output Messages or State Vector Reports for at least 45% of the Airborne Position Messages provided to the Bottom Channel RF input port.

2.4.14 Verification of Interfaces (§2.2.14)

No specific test procedure is required to validate §2.2.14.

2.4.14.1 Verification of ADS-B Transmitting Subsystem Interfaces (§2.2.14.1)

No specific test procedure is required to validate §2.2.14.1.

2.4.14.1.1 Verification of ADS-B Transmitting Subsystem Input Interfaces (§2.2.14.1.1)

No specific test procedure is required to validate §2.2.14.1.1.

2.4.14.1.1.1 Verification of Discrete Input Interfaces (§2.2.14.1.1.1)

Appropriate verification of discrete input interfaces to the ADS-B Transmitting Subsystem was demonstrated during testing of the entire transmission function performed in §2.4.2 and §2.4.3 of this document.

Note: *The manufacturer is required to document all intended data to be input via discrete inputs and ensure full and correct functioning of the ADS-B Transmitting Subsystem for all inputs at these interfaces. The manufacturer **shall** also demonstrate that appropriate diode isolation is provided for each input interface. Such demonstration can be done by formal documentation of the design such as schematics and Bill of Materials (BOM).*

2.4.14.1.1.2 Verification of Digital Communication Input Interfaces (§2.2.14.1.1.2)

Appropriate verification of digital communication input interfaces to the ADS-B Transmitting Subsystem was demonstrated during testing of the entire transmission function performed in §2.4.2 and §2.4.3 of this document.

Note: *The manufacturer is required to disclose the interface protocols and error control techniques used with these interfaces and to demonstrate correct functioning of theses interfaces in such regards. Traditionally, analysis and established knowledge of the interface (e.g., ARINC-429) have been sufficient to satisfy these interface integrity requirements.*

2.4.14.1.1.3 Verification of Processing Efficiency (§2.2.14.1.1.3)

Appropriate verification of the processing efficiency of interfaces to the ADS-B Transmitting Subsystem was demonstrated during testing of the entire transmission function performed in §2.4.2 and §2.4.3 of this document.

2.4.14.1.2 Verification of ADS-B Transmitting Subsystem Output Interfaces (§2.2.14.1.2)

No specific test procedure is required to validate §2.2.14.1.2.

2.4.14.1.2.1 Verification of Discrete Output Interfaces (§2.2.14.1.2.1)

Appropriate verification of discrete output interfaces from the ADS-B Transmitting Subsystem was demonstrated during testing of the entire transmission function performed in §2.4.2 and §2.4.3 of this document.

Note: *The manufacturer is required to document all intended data to be output via discrete interfaces and ensure full and correct functioning of the ADS-B Transmitting Subsystem for all outputs at these interfaces. The manufacturer **shall** also demonstrate that appropriate diode isolation is provided for each output interface. Such demonstration can be done by formal documentation of the design such as schematics and Bill of Materials (BOM).*

2.4.14.1.2.2 Verification of Digital Communication Output Interfaces (§2.2.14.1.2.2)

Appropriate verification of digital communication output interfaces from the ADS-B Transmitting Subsystem was demonstrated during testing of the entire transmission function performed in §2.4.2 and §2.4.3 of this document.

Note: *The manufacturer is required to disclose the interface protocols and error control techniques used with these interfaces and to demonstrate correct functioning of theses interfaces in such regards. Traditionally, analysis and established knowledge of the interface (e.g., ARINC-429) have been sufficient to satisfy these interface integrity requirements.*

2.4.14.2 Verification of ADS-B Receiving Device Interfaces (§2.2.14.2)

No specific test procedure is required to validate §2.2.14.2.

2.4.14.2.1 Verification of ADS-B Receiving Device Input Interfaces (§2.2.14.2.1)

No specific test procedure is required to validate §2.2.14.2.1.

2.4.14.2.1.1 Verification of Discrete Input Interfaces (§2.2.14.2.1.1)

Appropriate verification of discrete input interfaces to the ADS-B Receiving Subsystem was demonstrated during testing of the entire receiving function performed in §2.4.4 through §2.4.11 of this document.

Note: *The manufacturer is required to document all intended data to be input via discrete inputs and ensure full and correct functioning of the ADS-B Receiving Subsystem for all inputs at these interfaces. The manufacturer **shall** also demonstrate that appropriate diode isolation is provided for each input interface. Such demonstration can be done by formal documentation of the design such as schematics and Bill of Materials (BOM).*

2.4.14.2.1.2 Verification of Digital Communication Input Interfaces (§2.2.14.2.1.2)

Appropriate verification of digital communication input interfaces to the ADS-B Receiving Subsystem was demonstrated during testing of the entire receiving function performed in §2.4.4 through §2.4.11 of this document.

Note: *The manufacturer is required to disclose the interface protocols and error control techniques used with these interfaces and to demonstrate correct functioning of theses interfaces in such regards. Traditionally, analysis and established knowledge of the interface (e.g., ARINC-429) have been sufficient to satisfy these interface integrity requirements.*

2.4.14.2.1.3 Verification of Processing Efficiency (§2.2.14.2.1.3)

Appropriate verification of processing efficiency of interfaces to the ADS-B Receiving Subsystem was demonstrated during testing of the entire receiving function performed in §2.4.4 through §2.4.11 of this document.

2.4.14.2.2 Verification of ADS-B Receiving Device Output Interfaces (§2.2.14.2.2)

No specific test procedure is required to validate §2.2.14.2.2.

2.4.14.2.2.1 Verification of Discrete Output Interfaces (§2.2.14.2.2.1)

Appropriate verification of discrete output interfaces from the ADS-B Receiving Subsystem was demonstrated during testing of the entire receiving function performed in §2.4.4 through §2.4.11 of this document.

Note: *The manufacturer is required to document all intended data to be output via discrete interfaces and ensure full and correct functioning of the ADS-B Receiving Subsystem for all outputs at these interfaces. The manufacturer **shall** also demonstrate that appropriate diode isolation is provided for each output interface. Such demonstration can be done by formal documentation of the design such as schematics and Bill of Materials (BOM).*

2.4.14.2.2.2 Verification of Digital Communication Output Interfaces (§2.2.14.2.2.2)

Appropriate verification of digital communication output interfaces from the ADS-B Receiving Subsystem was demonstrated during testing of the entire receiving function performed in §2.4.4 through §2.4.11 of this document.

Note: *The manufacturer is required to disclose the interface protocols and error control techniques used with these interfaces and to demonstrate correct functioning of theses interfaces in such regards. Traditionally, analysis and established knowledge of the interface (e.g., ARINC-429) have been sufficient to satisfy these interface integrity requirements.*

2.4.15 Verification of Power Interruption (§2.2.15)

No specific test procedure is required to validate §2.2.15.

2.4.15.1 Verification of Power Interruption to ADS-B Transmitting Subsystems (§2.2.15)

Purpose/Introduction:

These test procedures verify that the ADS-B Transmitting Subsystem regains operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

Equipment Required:

Provide equipment capable of loading valid data for ADS-B broadcast messages into the ADS-B Transmitting Subsystem under test through the operational interface.

Measurement Procedure:

Step 1: Enable Transmission of Airborne Position Messages

Supply the ADS-B Transmitting Subsystem with the appropriate data necessary to establish Airborne Position Messages.

Verify that the ADS-B Transmitting Subsystem generates appropriate Airborne Position Messages at the rate specified in §2.2.3.3.1.1 or §2.2.3.3.2.2.

Note: *If the ADS-B Transmitting Subsystem uses diversity and the test is being performed on one RF output interface at a time, then the specified rate necessary to satisfy this test is half of that given in §2.2.3.3.1.1 or §2.2.3.3.2.2.*

Step 2: Apply momentary power interrupts

Apply momentary power interrupts to the ADS-B Transmitting Subsystem under test in accordance with RTCA DO-160F section 16 (EUROCAE ED-14F, section 16). Then restore the power to normal operating conditions.

Verify that the ADS-B Transmitting Subsystem resumes generation of appropriate Airborne Position Messages no later than 2.0 seconds after the restoration of normal power.

Step 3: Repeat for additional RF Output Interfaces

If the ADS-B Transmitting Subsystem implements diversity, then repeat steps 1 and 2 on the additional RF Output Interface.

2.4.15.2 Verification of Power Interruption to ADS-B Receiving Subsystems (§2.2.15)

Purpose/Introduction:

These test procedures verify that the ADS-B Receiving Subsystem regains operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

Equipment Required:

An equipment capable of supplying valid ADS-B broadcast messages to the ADS-B Receiving Subsystem under test via the appropriate RF interface.

Measurement Procedure:

Step 1: Enable Reception of Airborne Position Messages

Via the receiver RF interface and in the absence of interference, apply valid 1090 MHz Airborne Position Messages at a uniform rate of 2 per second and at a signal level that is at least 15 dB above the MTL of the ADS-B Receiving Subsystem.

Verify that the ADS-B Receiving Subsystem delivers appropriate Output Messages to the user interface or to the Report Assembly function for all messages received and that the Output Message formats are consistent with the requirements of §2.2.6.1.1.

Step 2: Apply momentary power interrupts

Apply momentary power interrupts to the ADS-B Receiving Subsystem under test in accordance with RTCA DO-160F section 16 (EUROCAE ED-14F, section 16). Then restore the power to normal operating conditions.

Verify that the ADS-B Receiving Subsystem resumes generation of appropriate Output Messages to the user interface or to the Report Assembly function no later than 2.0 seconds after the restoration of power.

Then verify that the ADS-B Receiving Subsystem continues to deliver appropriate Output Messages to the user interface or to the Report Assembly function for all messages received and that the Output Message formats are consistent with the requirements of §2.2.6.1.1.

Step 3: Repeat for additional RF Output Interfaces

If the ADS-B Receiving Subsystem implements diversity, then repeat steps 1 and 2 on the additional RF Input Interface.

2.4.16 Verification of Compatibility with Other Systems (§2.2.16)

No specific test procedure is required to validate §2.2.16.

2.4.16.1 Verification of EMI Compatibility (§2.2.16.1)

Verification of EMI/EMC/HIRF/LIGHTNING compatibility is performed during Environmental testing in accordance with RTCA DO-160F (EUROCAE ED-14F) with the test procedures provided in Section 2.3 of this document.

2.4.16.2 Verification of Compatibility with GPS Receivers (§2.2.16.2)

Verification of compatibility with GPS Receivers is demonstrated during verification of EMI/EMC/HIRF/LIGHTNING compatibility performed during Environmental testing in accordance with RTCA DO-160F (EUROCAE ED-14F) with the test procedures provided in Section 2.3 of this document.

2.4.16.3 Verification of Compatibility with Other Navigation Receivers and ATC Transponders (§2.2.16.3)

Verification of compatibility with Other Navigation Receivers and ATC Transponders is demonstrated during verification of EMI/EMC/HIRF/LIGHTNING compatibility performed during Environmental testing in accordance with RTCA DO-160F (EUROCAE ED-14F) with the test procedures provided in §2.3 of this document.

2.4.17 Verification of Traffic Information Services – Broadcast (TIS-B) (§2.2.17)

No specific test procedure is required to validate the requirements of §2.2.17.

2.4.17.1 Verification of TIS-B Introduction (§2.2.17.1)

No specific test procedure is required to validate the requirements of §2.2.17.1.

2.4.17.2 Verification of the TIS-B Format Structure (§2.2.17.2)

No specific test procedure is required to validate the requirements of §2.2.17.2.

2.4.17.2.1 Verification of the “DF” Downlink Format (§2.2.17.2.1)

No specific test procedure is required to validate §2.2.17.2.1.

2.4.17.2.2 Verification of the “CF” Control Field (§2.2.17.2.2)

Purpose/Introduction:

These test procedures verify the use of the “CF” field of DF=18 messages being used by Non-Transponder-Based installations as specified in §2.2.17.2.2.

Measurement Procedure:

Step 1: Verification of DF=18, CF=2

Set up to transmit TIS-B Messages. Input a simulated ADS-B DF=18, CF=2 Message. Verify that a TIS-B Report is generated.

Step 2: Verification of DF=18, CF=3

Set up to transmit TIS-B Messages. Input a simulated ADS-B DF=18, CF=3 Message. Verify that a TIS-B Report is generated.

Step 3: Verification of DF=18, CF=4

Set up to transmit TIS-B Messages. Input a simulated ADS-B DF=18, CF=4 Message. Verify that a TIS-B Report is generated containing the full 112-bits of the received 1090ES Message.

Step 4: Verification of DF=18, CF=5

Set up to transmit TIS-B Messages. Input a simulated ADS-B DF=18, CF=5 and IMF=0 Message. Verify that a TIS-B Report is generated. Input a simulated ADS-B DF=18, CF=5 and IMF=1 Message. Verify that a TIS-B Report is not generated.

Step 5: Verification of DF=18, CF=6

Set up to transmit TIS-B Messages. Input a simulated ADS-B Message with DF=18 and CF=6. Verify that a TIS-B Report is generated.

2.4.17.2.3 Verification of the "AA" Address Announced Field (§2.2.17.2.3)

Purpose/Introduction:

These test procedures verify the use of the AA Address field as specified in Table 2-106, and §2.2.17.2.3.

Measurement Procedure:

Step 1: Verification of the (ICAO) AA Content in a Fine TIS-B Message

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated Fine TIS-B DF=18 Message with CF=2 and IMF=0.

Verify that the CF field holds the value TWO (binary 010) and that the ICAO/Mode A Flag (IMF) is set to ZERO (0) in the output TIS-B Report.

Step 2: Verification of the (Mode A) AA Content in a Fine TIS-B Message

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated Fine TIS-B DF=18 Message with CF=2 and IMF=1.

Verify that the CF field holds the value TWO (binary 010) and that the ICAO/Mode A Flag (IMF) is set to ONE (1) in the output TIS-B Report.

Step 3: Verification of the (ICAO) AA Content in a Coarse TIS-B Message

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated Coarse TIS-B DF=18 Message with CF=3 and IMF=0.

Verify that the CF field holds the value THREE (binary 011) and that the ICAO/Mode A Flag (IMF) is set to ZERO (0) in the output TIS-B Report.

Step 4: Verification of the (Mode A) AA Content in a Coarse TIS-B Message

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated Coarse TIS-B DF=18 Message with CF=3 and IMF=1.

Verify that the CF field holds the value THREE (binary 011) and that the ICAO/Mode A Flag (IMF) is set to ONE (1) in the output TIS-B Report.

2.4.17.2.4 Verification of the "ME" Message Extended Squitter Field (§2.2.17.2.4)

No specific test is required to validate §2.2.17.2.4.

2.4.17.2.5 Verification of the "PI" Parity/Identify Field (§2.2.17.2.5)

No specific test is required to validate §2.2.17.2.5.

2.4.17.3 Verification of TIS-B Messages (§2.2.17.3)

No specific test is required to validate §2.2.17.3.

2.4.17.3.1 Verification of TIS-B Fine Airborne Position Message (§2.2.17.3.1)

No specific test is required to validate §2.2.17.3.1.

2.4.17.3.1.1 Verification of the Relationship to ADS-B Format (§2.2.17.3.1.1)

Purpose/Introduction:

This test procedure verifies that the following fields are decoded as specified for the ADS-B Airborne Position Message defined in §2.2.3.2.3:

TYPE Code	Surveillance Status
Altitude	CPR Format
Encoded Latitude	Encoded Longitude

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Fine Airborne Position Message.

Verify that the input TYPE, Surveillance Status, Altitude, CPR Format, Encoded Latitude and Encoded Longitude fields are all reflected in the output TIS-B Report. Repeat this procedure for TYPE Codes 9 through 18 and 20, 21 and 22, which are the TYPE Codes of the Airborne Position Message.

2.4.17.3.1.2 Verification of the ICAO/Mode A Flag (IMF) (§2.2.17.3.1.2)

Purpose/Introduction:

These test procedures verify that the ICAO/Mode A Flag is set as specified in §2.2.17.3.1.2.

Measurement Procedure:

Step 1: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – ICAO

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ZERO (0). Verify that the ICAO/Mode A Flag (IMF) is set to ZERO (0) in the output TIS-B Report.

Step 2: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – Mode A

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ONE (1). Verify that the ICAO/Mode A Flag (IMF) is set to ONE (1) in the output TIS-B Report.

2.4.17.3.2 Verification of TIS-B Fine Surface Position Message (§2.2.17.3.2)

No specific test is required to validate §2.2.17.3.2.

2.4.17.3.2.1 Verification of the Relationship to ADS-B Format (§2.2.17.3.2.1)

Purpose/Introduction:

These test procedures verify that the following fields are decoded as specified for the ADS-B Surface Position Message defined in §2.2.3.2.4:

TYPE Code	Movement
Heading Status	Heading
CPR Format	Encoded Latitude
Encoded Longitude	

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Fine Surface Position Message. Verify that the input TYPE, Movement, Ground Track Status, CPR Format, Encoded Latitude and Encoded Longitude fields are all reflected in the output TIS-B Report. Repeat this procedure for TYPE Codes 5 through 8, which are the TYPE Codes for the Surface Position Messages.

2.4.17.3.2.2 Verification of the ICAO/Mode A Flag (IMF) (§2.2.17.3.2.2)

Purpose/Introduction:

This test procedure verifies that the ICAO/Mode A Flag is set as specified in §2.2.17.3.1.2.

Measurement Procedure:

Step 1: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – ICAO

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ZERO (0). Verify that the ICAO/Mode A Flag (IMF) is set to ZERO (0) in the output TIS-B Report.

Step 2: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – Mode A

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ONE (1). Verify that the ICAO/Mode A Flag (IMF) is set to ONE (1) in the output TIS-B Report.

2.4.17.3.3 TIS-B Identification and Category Message (§2.2.17.3.3)

No specific test is required to validate §2.2.17.3.3.

2.4.17.3.3.1 Verification of the Relationship to ADS-B Format (§2.2.17.3.3.1)

Purpose/Introduction:

These test procedures verify that all of the fields of the TIS-B Identification and Category Message are decoded as specified for the ADS-B Identification and Category Message specified in §2.2.3.2.5.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Identification and Category Message with a TYPE Code equal 1. Verify that all of the input data fields in Figure 2-27 are reflected in the output TIS-B Report. Repeat this procedure for TYPE Codes 2, 3 and 4.

2.4.17.3.4 Verification of TIS-B Velocity Message (§2.2.17.3.4)

No specific test is required to validate §2.2.17.3.4.

2.4.17.3.4.1 Verification of the Relationship to ADS-B Format (§2.2.17.3.4.1)

Purpose/Introduction:

Theses test procedures verify that the following fields are decoded as specified for the ADS-B Velocity Message with Subtype=1, as specified in §2.2.3.2.6.1, or Subtype=2, as specified in §2.2.3.2.6.2:

TYPE Code	Subtype Code
E/W Direction Bit	E/W Velocity
N/S Direction Bit	N/S Velocity
Vertical Rate Sign	Vertical Rate
Height Difference Sign Bit	Geometric Height Difference from Baro
Vertical Rate Type	

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message, TYPE=19, Subtype=1.

Verify that the input TYPE, Subtype, E/W Direction Bit, E/W Velocity, N/S Direction Bit, N/S Velocity, "Sign Bit for Vertical Rate," "Vertical Rate," "Height Difference Sign Bit," "Geometric Height Difference from Baro," and "Vertical Rate Type" subfields are all reflected in the output TIS-B Report. Repeat this procedure for TIS-B Velocity Messages, TYPE=19 and Subtype=2.

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message, TYPE=19, Subtype=1, GEO=1. Verify that the input Vertical Rate Type, Height Difference Sign Bit and Geometric Height Difference from Baro are all reflected in the output TIS-B

Report. Repeat this procedure for TIS-B Velocity Messages, TYPE=19 and Subtype=2, GEO=1.

2.4.17.3.4.2 Verification of ICAO/Mode A Flag (IMF) (§2.2.17.3.4.2)

Purpose/Introduction:

This test procedure verifies that the ICAO/Mode A Flag is set as specified in §2.2.17.3.1.2.

Measurement Procedure:

Step 1: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – ICAO

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ZERO (0). Verify that the ICAO/Mode A Flag (IMF) is set to ZERO (0) in the output TIS-B Report.

Step 2: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – Mode A

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ONE (1). Verify that the ICAO/Mode A Flag (IMF) is set to ONE (1) in the output TIS-B Report.

2.4.17.3.4.3 Verification of Navigation Integrity Category (NIC) Supplement-A (§2.2.17.3.4.3)

Purpose/Introduction:

This test procedure verifies that the NIC Supplement-A bit (“ME” bit 47) field is used together with the Message TYPE Code to define the NIC value for the Airborne and Surface Position Messages. Coding of the NIC Supplement-A field is specified for the Aircraft Operational Status Message in Table N-XX.

Measurement Procedure:

Step 1: Verification of NIC Supplement

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message containing pseudo-random data and include valid values in the Airborne Position Message TYPE Code and NIC Supplement-A subfields.

Verify that for each Airborne Position Message TYPE Code and NIC Supplement-A value in Table N-XX, that the corresponding NIC value is reflected in the output TIS-B Report.

2.4.17.3.4.4 Verification of the Navigation Accuracy Category for Position (NAC_P) (§2.2.17.3.4.4)

Purpose/Introduction:

This test procedure verifies the use of the four-bit ("ME" bits 10 through 13) field that defines the NAC_P value for the Airborne and Surface Position Messages. Coding of the NAC_P field is specified for the Aircraft Operational Status Message in Table 2-71.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message containing pseudo-random data but include valid values in the NAC_P field as per Table 2-71. Verify that each input NAC_P value so entered is reflected in the output TIS-B Report.

2.4.17.3.4.5 Verification of the Navigation Accuracy Category for Velocity (NAC_V) (§2.2.17.3.4.5)

Purpose/Introduction:

This test procedure verifies the use of the 3-bit ("ME" bits 48 through 50) field that defines the NAC_V value for the Airborne Velocity Message when the GEO Flag is equal to ZERO (0). Coding of the NAC_V field is specified in §2.2.3.2.6.1.5.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message TYPE=19 with the GEO Flag set to ZERO (0) and containing pseudo-random data but include valid values in the NAC_V field as per Table 2-25. Verify that each input NAC_V value so entered is reflected in the output TIS-B Report.

2.4.17.3.4.6 Verification of the Source Integrity Level (SIL) (§2.2.17.3.4.6)

Purpose/Introduction:

This test procedure verifies the use of the two-bit ("ME" bits 52 and 53) field that defines the SIL value for the Airborne and Surface Position Messages when the GEO Flag is equal to ZERO (0). Coding of the SIL field is specified in Table N-XX.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message TYPE=19 with the GEO Flag set to ZERO (0) and containing pseudo-random data but include valid values in the SIL field as per Table N-XX. Verify that each input SIL value so entered is reflected in the output TIS-B Report.

2.4.17.3.4.7 Verification of the True/Magnetic Heading Type (§2.2.17.3.4.7)

Purpose/Introduction:

This test procedure verifies the use of the one-bit ("ME" bit 55) field that defines the True or Magnetic Heading value for the Airborne Velocity Message when the GEO Flag is equal to ZERO (0) for a Subtype of 3 or 4. Coding of the True/Magentic Heading Type field is specified in §2.2.3.2.7.2.13.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B Velocity Message TYPE=19 with the GEO Flag set to ZERO (0) and containing pseudo-random data but include valid values in the HRD field as per Table 2-76. Verify that each input HRD value so entered is reflected in the output TIS-B Report.

2.4.17.3.5 Verification of the TIS-B Coarse Position Message (§2.2.17.3.5)

No specific test is required to validate §2.2.17.3.5.

2.4.17.3.5.1 Verification of the Relationship to ADS-B Format (§2.2.17.3.5.1)

No specific test is required to validate §2.2.17.3.5.1.

2.4.17.3.5.2 Verification of the ICAO/Mode A Flag (IMF) (§2.2.17.3.5.2)

Purpose/Introduction:

This test procedure verifies that the ICAO/Mode A Flag is set as specified in §2.2.17.3.1.2.

Measurement Procedure:

Step 1: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – ICAO

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ZERO (0). Verify that the ICAO/Mode A Flag (IMF) is set to ZERO (0) in the output TIS-B Report.

Step 2: Verification of the ICAO/Mode A Flag (IMF) in a TIS-B Message – Mode A

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B DF=18 Message such that the IMF Flag is set to ONE (1). Verify that the ICAO/Mode A Flag (IMF) is set to ONE (1) in the output TIS-B Report.

2.4.17.3.5.3 Verification of the Service Volume ID (SVID) (§2.2.17.3.5.3)

Purpose/Introduction:

This test procedure verifies that the 4-bit SVID field ("ME" bits 4 through 7) is properly decoded to identify the TIS-B site that delivered the surveillance data.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated even formatted TIS-B Message and, within ten seconds, an odd formatted TIS-B Message with an identical SVID field. This will complete a track and indicate that both messages came from the same TIS-B station. Verify that the subsequent output TIS-B Report reflects the value in the SVID field in the input messages.

2.4.17.3.5.4 Verification of the Pressure Altitude (§2.2.17.3.5.4)

Appropriate test procedures to verify §2.2.17.3.5.4 are provided in §2.4.3.2.3.4.1 and §2.2.3.2.3.4.2.

2.4.17.3.5.5 Verification of the Ground Track Status (§2.2.17.3.5.5)

Purpose/Introduction:

This test procedure verifies the one bit ("ME" bit 20) field that defines the validity of the Ground Track value as specified in §2.2.17.3.5.5.

Measurement Procedure:

Step 1: Verification of Ground Track Status – Valid

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B coarse position message with ("ME" bit 20) set to ONE (1). Verify that the contents of Ground Track Angle field are reflected in the next output TIS-B Report and that the validity bit ("ME" bit 20) is set to ONE (1).

Step 2: Verification of Ground Track Status – Not Valid

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B coarse position message with ("ME" bit 20) set to ZERO (0). Verify that the contents of Ground Track Angle field are **not** reflected in the next output TIS-B Report and that the validity bit ("ME" bit 20) is set to ZERO (0).

2.4.17.3.5.6 Verification of the Ground Track Angle (§2.2.17.3.5.6)

Purpose/Introduction:

This test procedure verifies the 5-bit ("ME" bits 21 through 25) field that defines the direction (in degrees clockwise from true north) of aircraft motion. The Ground Track is encoded as an unsigned angular weighted binary numeral, with an MSB of 180 degrees and an LSB of 360/32 degrees, with ZERO (0) indicating true north. The data in the field is rounded to the nearest multiple of 360/32 degrees.

Measurement Procedure:

Step 1: Verification of Ground Track Angle – Input Validation

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B coarse position message. Provide valid, non-zero "Ground Track Angle" data to the receiver. Verify that the "Ground Track Angle" subfield is **not** set to ZERO (0). Set the "Ground Track Angle" input to exactly ZERO degrees and verify that the encoding of the "Ground Track Angle" subfield is set to ZERO (binary 0 0000) in the output TIS-B Report.

Step 2: Verification of Ground Track Angle – Discreet Values

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B message with a "Ground Track Angle" input set to binary 0 0001. Verify that a Ground Track value of 11.25 degrees is reflected in the output TIS-B Report. Continue increasing the "Ground Track Angle" data input value and verify that, for each such input set to the corresponding binary value in each row shown in Table 2-204, the "Ground Track Angle" in degrees is correctly reflected in the output TIS-B Report.

Table 2-204: "Ground Track Angle" Encoding

Coding		**Meaning** (Ground Track in degrees)
(Binary)	(Decimal)	
0 0000	0	Ground Track is ZERO
0 0001	1	Ground Track = 11.25 degrees
0 0010	2	Ground Track = 22.50 degrees
0 0011	3	Ground Track = 33.75 degrees
***	***	***
1 1110	30	Ground Track = 337.50 degrees
1 1111	31	Ground Track = 348.75 degrees

2.4.17.3.5.7 Verification of the Ground Speed (§2.2.17.3.5.7)

Purpose/Introduction:

This test procedure verifies the 6-bit ("ME" bits 26 through 31) field that defines the aircraft speed over the ground. Coding of this field is specified in Table 2-107.

Measurement Procedure:

Step 1: Verification of Ground Speed – Data Not Available

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B coarse position message with ("ME" bits 26-31) set to ALL ZEROs (binary 00 0000) to indicate "data not available." Verify that "data not available" for ground speed is reflected in the output TIS-B Report.

Step 2: Verification of Ground Speed – Discrete Values

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B coarse position message with ("ME" bits 26-31) set to ONE (binary 00 0001) to indicate a ground speed less than 16 knots.

Verify that ground speed less than 16 knots is reflected in the output TIS-B Report. Repeat this step for eight more values chosen at random from Table 2-107 and, in each case, verify that the input value is correctly reflected in the output TIS-B Report.

2.4.17.3.5.8 Verification of the 12-bit CPR Decoded Latitude and Longitude (§2.2.17.3.5.8)

Purpose/Introduction:

The "ENCODED LATITUDE" and the "ENCODED LONGITUDE" subfields are 12-bit fields, ME Bits 33 through 44 and ME bits 45 through 56, in the TIS-B Coarse Position Message. The following test procedure verifies that the ADS-B Transmitting Subsystem correctly receives Latitude and Longitude position data from the incoming TIS-B Coarse Position Message and outputs decoded Latitude and Longitude data in the TIS-B Report.

The following procedure verifies the static Latitude and Longitude decoding where the velocity input is 0.0 knots to verify the actual CPR Latitude and Longitude decoding precision.

Measurement Procedure:

The "Encoded Latitude" and the "Encoded Longitude" subfields are 12-bit fields (ME Bits 33 through 44 and ME Bits 45 through 56) in the TIS-B Coarse Position Message. The following test procedure verifies that the ADS-B Receiving Subsystem correctly receives Latitude and Longitude position data from the incoming TIS-B Coarse Position Message and outputs decoded Latitude and Longitude data in the TIS-B Report. The Latitude and

Longitude data are encoded according to the Compact Position Reporting (CPR) Format described in Appendix A. The Latitude and Longitude data are dependent upon the positional accuracy supported by the TIS-B site.

The following procedure verifies the static Latitude and Longitude encoding where the velocity input is 0.0 knots to verify the actual CPR Latitude and Longitude decoding precision.

Step 1: Establish Initial Conditions

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem being sure to set the velocity input to ZERO (0).

Step 2: Verify Encoded Latitude and Longitude Data

1. Provide the ADS-B Receiving Subsystem with an "**even**" formatted TIS-B Coarse Airborne Position Message containing the exact latitude and longitude data pair provided in the first row of the Even Airborne Encoding Column in Table 2-205.

2. Within ten seconds, provide the ADS-B Receiving Subsystem with an "**odd**" formatted TIS-B Coarse Airborne Position Message containing the exact latitude and longitude data pair provided in the first row of the Odd Airborne Encoding Column in Table 2-205.

3. For each Even interval TIS-B Coarse Position Message that is simulated:

   Verify that the "CPR Format" (F) subfield is set to ZERO (0).

   For each Odd interval TIS-B Coarse Position Message that is simulated:

   Verify that the "CPR Format" (F) subfield is set to ONE (1).

   Verify that the Reported Binary decoded Latitude and Longitude datum, in the output TIS-B Report, match the corresponding values in the Angular Weighted Binary columns on the same row in Table 2-205.

   If the decoding is not exact, verify that the decoding does not differ from the table value by more than "1" Least Significant Bit (LSB).

   If the decoded value differs from the table value by more than "1" LSB, then the test is considered to have failed. Other wise the test is passed.

   Repeat this procedure for each row in Table 2-205.

Table 2-205: 12-bit CPR Airborne Position Encoding Values

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	Latitude HEX	Longitude Decimal	Longitude HEX	Latitude HEX	Longitude HEX	Latitude HEX	Longitude HEX
-90.0000	C0000000	-180.0000	80000000	000	800	400	800
-89.9500	C0091A2B	179.5000	7FA4FA50	022	7FA	422	7FA
-89.5000	C05B05B0	178.5000	7EEEEEEF	155	7EF	550	7EF
-89.0000	C0B60B61	175.5000	7CCCCCCD	2AB	7CD	69F	7CD
-87.5000	C1C71C72	-165.0000	8AAAAAAB	6AB	8AB	A8E	8AB
-86.7500	C24FA4FA	-171.5000	860B60B6	8AB	0C1	C86	861
-86.5000	C27D27D2	-172.5000	85555555	955	900	D2E	0AB
-85.8500	C2F37C05	65.7500	2EC16C17	B11	8C4	EE2	5D8
-85.0000	C38E38E4	-142.7500	9A7D27D2	D55	69F	11C	CF7
-84.2500	C416C16C	60.0000	2AAAAAAB	F55	D55	314	AAB
-83.5500	C4962FC9	-60.0000	D5555555	133	000	4EA	2AB
-82.6800	C53490BA	120.0000	55555555	385	555	732	000
-81.7500	C5DDDDDE	-120.0000	AAAAAAAB	600	555	9A2	AAB
-80.2500	C6EEEEEF	144.0000	66666666	A00	99A	D91	333
-79.7500	C749F49F	-144.0000	9999999A	B55	000	EE1	666
-78.4000	C83FB7F2	-121.0000	A9F49F4A	EEF	4D8	26B	A39
-77.4000	C8F5C28F	121.0000	560B60B6	19A	089	50A	B28
-76.5500	C9907F6E	-154.2800	924A2EE0	3DE	6DC	745	DB8
-75.6000	CA3D70A4	154.2800	6DB5D120	666	FFF	9C3	924
-74.7500	CAD82D83	157.5000	70000000	8AB	900	BFD	200
-73.6500	CBA06D3A	-157.5000	90000000	B9A	000	EE0	700
-72.7500	CC444444	-120.0000	AAAAAAAB	E00	555	13C	AAB
-71.5500	CD1EB852	120.0000	55555555	133	000	461	AAB
-70.6500	CDC28F5C	-144.0000	9999999A	39A	666	6BD	CCD
-69.5500	CE8ACF13	144.0000	66666666	689	000	9A0	99A
-68.7500	CF1C71C7	-114.5500	AE8ACF13	8AB	516	BB9	A2E
-67.7500	CFD27D28	114.5500	517530ED	B55	001	E58	AEA
-66.5500	D0ACF135	-67.5000	D0000000	E89	B00	17E	E00
-65.5500	D162FC96	67.5000	30000000	133	800	41D	500
-64.4500	D22B3C4D	-83.0800	C4EBBF60	422	3B0	6FF	762
-63.2500	D305B05B	83.0800	3B1440A0	755	001	A25	C50
-62.2500	D3BBBBBC	-64.2900	D2485CD8	A00	2DA	CC4	5B6
-61.2500	D471C71C	64.2900	2DB7A328	CAB	001	F64	D26
-60.2500	D527D27D	-72.0000	CCCCCCCD	F55	333	203	666
-59.9600	D55C9D78	-120.5000	AA4FA4FA	01B	4B0	2C6	A0B
-59.9300	D5621392	-119.5000	AB05B05B	030	0AB	2DA	5FA
-58.0000	D6C16C17	-78.7500	C8000000	555	380	7E9	700
-58.5000	D6666666	78.7500	38000000	400	C80	69A	900
-57.9500	D6CA8642	-22.5000	F0000000	577	100	80B	200
-56.8500	D792C5F9	22.5000	10000000	866	000	AED	F00
-55.5000	D8888889	-52.9400	DA5A912E	C00	25B	E77	4B5
-54.6200	D928BB81	52.9400	25A56ED2	E59	000	0C6	DA5
-53.2500	DA222222	-30.0000	EAAAAAAB	200	155	45E	2AB
-51.9500	DB0ECA86	30.0000	15555555	577	000	7C7	EAB

Table 2-205: 12-bit CPR Airborne Position Encoding Values (Continued)

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	**Latitude HEX**	**Longitude Decimal**	**Longitude HEX**	**Latitude HEX**	**Longitude HEX**	**Latitude HEX**	**Longitude HEX**
-50.7500	DBE93E94	-75.7900	CA1ADA00	8AB	35E	AEC	6BC
-49.6500	DCB17E4B	75.7900	35E52600	B9A	000	DCF	CA2
-48.2500	DDB05B06	-27.0000	ECCCCCCD	F55	133	17A	266
-47.0000	DE93E93F	27.0000	13333333	2AB	000	4C1	ECD
-45.6000	DF92C5F9	-68.5700	CF3D3663	666	30D	86D	619
-44.2500	E0888889	-180.0000	80000000	A00	000	BF7	800
-42.8500	E1876543	179.5000	7FA4FA50	DBC	70B	FA3	F11
-41.4000	E28F5C29	178.5000	7EEEEEEF	19A	D11	371	522
-40.0000	E38E38E4	175.5000	7CCCCCCD	555	F00	71C	733
-38.5000	E49F49F5	-160.9000	8D950C84	955	70D	B0B	E33
-36.9000	E5C28F5C	-171.5000	860B60B6	D9A	9C1	F3D	161
-35.2500	E6EEEEEF	-172.5000	85555555	200	000	391	7AB
-33.6000	E81B4E82	65.7500	2EC16C17	666	F30	7E5	C44
-31.8000	E962FC96	-142.7500	9A7D27D2	B33	2C7	C9D	91F
-30.0000	EAAAAAAB	59.5000	2A4FA4FA	000	6DE	155	439
-28.0000	EC16C16C	-60.0000	D5555555	555	555	694	800
-25.9000	ED950C84	-66.7000	D091A2B4	AEF	2E2	C16	5D9
-23.6000	EF37C049	-120.0000	AAAAAAAB	111	000	21E	555
-21.1000	F0FEDCBB	41.5000	1D82D82E	7BC	572	8AC	39A
-18.2000	F30ECA86	-144.0000	9999999A	F77	99A	047	000
-14.9000	F56789AC	-121.0000	A9F49F4A	844	D77	8EE	2D8
-10.5000	F8888889	121.0000	560B60B6	400	7E9	477	289
-5.1000	FC5F92C6	6.2500	0471C71C	266	064	2A0	01C
-2.5000	FE38E38E	154.2800	6DB5D120	955	48E	972	DB3
0.0000	00000000	60.0000	2AAAAAAB	000	D55	000	AAB
0.0000	00000000	-157.5000	90000000	000	300	000	A00
90.0000	40000000	-180.0000	80000000	000	800	C00	800
89.9500	3FF6E5D5	179.5000	7FA4FA50	FDE	7FA	BDE	7FA
89.5000	3FA4FA50	178.5000	7EEEEEEF	EAB	7EF	AB0	7EF
89.0000	3F49F49F	175.5000	7CCCCCCD	D55	7CD	961	7CD
87.5000	3E38E38E	-165.0000	8AAAAAAB	955	8AB	572	8AB
86.7500	3DB05B06	-171.5000	860B60B6	755	0C1	37A	861
86.5000	3D82D82E	-172.5000	85555555	6AB	900	2D2	0AB
85.8500	3D0C83FB	65.7500	2EC16C17	4EF	8C4	11E	5D8
85.0000	3C71C71C	-142.7500	9A7D27D2	2AB	69F	EE4	CF7
84.2500	3BE93E94	60.0000	2AAAAAAB	0AB	D55	CEC	AAB
83.5500	3B69D037	-60.0000	D5555555	ECD	000	B16	2AB
82.6800	3ACB6F46	120.0000	55555555	C7B	555	8CE	000
81.7500	3A222222	-120.0000	AAAAAAAB	A00	555	65E	AAB
80.2500	39111111	144.0000	66666666	600	99A	26F	333
79.7500	38B60B61	-144.0000	9999999A	4AB	000	11F	666
78.4000	37C048D1	-121.0000	A9F49F4A	111	4D8	D95	A39
77.4000	370A3D71	121.0000	560B60B6	E66	089	AF6	B28
76.5500	366F8092	-154.2800	924A2EE0	C22	6DC	8BB	DB8
75.6000	35C28F5C	154.2800	6DB5D120	99A	FFF	63D	924
74.7500	3527D27D	157.5000	70000000	755	900	403	200
73.6500	345F92C6	-157.5000	90000000	466	000	120	700
72.7500	33BBBBBC	-120.0000	AAAAAAAB	200	555	EC4	AAB
71.5500	32E147AE	120.0000	55555555	ECD	000	B9F	AAB
70.6500	323D70A4	-144.0000	9999999A	C66	666	943	CCD
69.5500	317530ED	144.0000	66666666	977	000	660	99A

Table 2-205: 12-bit CPR Airborne Position Encoding Values (Continued)

Angular Weighted Binary Values (degrees)				Even Airborne Encoding		Odd Airborne Encoding	
Latitude Decimal	**Latitude HEX**	**Longitude Decimal**	**Longitude HEX**	**Latitude HEX**	**Longitude HEX**	**Latitude HEX**	**Longitude HEX**
68.7500	30E38E39	-114.5500	AE8ACF13	755	516	447	A2E
67.7500	302D82D8	114.5500	517530ED	4AB	001	1A8	AEA
66.5500	2F530ECB	-67.5000	D0000000	177	B00	E82	E00
65.5500	2E9D036A	67.5000	30000000	ECD	800	BE3	500
64.4500	2DD4C3B3	-83.0800	C4EBBF60	BDE	3B0	901	762
63.2500	2CFA4FA5	83.0800	3B1440A0	8AB	001	5DB	C50
62.2500	2C444444	-64.2900	D2485CD8	600	2DA	33C	5B6
61.2500	2B8E38E4	64.2900	2DB7A328	355	001	09C	D26
60.2500	2AD82D83	-72.0000	CCCCCCCD	0AB	333	DFD	666
59.9600	2AA36288	-120.5000	AA4FA4FA	FE5	4B0	D3A	A0B
59.9300	2A9DEC6E	-119.5000	AB05B05B	FD0	0AB	D26	5FA
58.0000	293E93E9	-78.7500	C8000000	AAB	380	817	700
58.5000	2999999A	78.7500	38000000	C00	C80	966	900
57.9500	293579BE	-22.5000	F0000000	A89	100	7F5	200
56.8500	286D3A07	22.5000	10000000	79A	000	513	F00
55.5000	27777777	-52.9400	DA5A912E	400	25B	189	4B5
54.6200	26D7447F	52.9400	25A56ED2	1A7	000	F3A	DA5
53.2500	25DDDDDE	-30.0000	EAAAAAAB	E00	155	BA2	2AB
51.9500	24F1357A	30.0000	15555555	A89	000	839	EAB
50.7500	2416C16C	-75.7900	CA1ADA00	755	35E	514	6BC
49.6500	234E81B5	75.7900	35E52600	466	000	231	CA2
48.2500	224FA4FA	-27.0000	ECCCCCCD	0AB	133	E86	266
47.0000	216C16C1	27.0000	13333333	D55	000	B3F	ECD
45.6000	206D3A07	-68.5700	CF3D3663	99A	30D	793	619
44.2500	1F777777	-180.0000	80000000	600	000	409	800
42.8500	1E789ABD	179.5000	7FA4FA50	244	70B	05D	F11
41.4000	1D70A3D7	178.5000	7EEEEEEF	E66	D11	C8F	522
40.0000	1C71C71C	175.5000	7CCCCCCD	AAB	F00	8E4	733
38.5000	1B60B60B	-160.9000	8D950C84	6AB	70D	4F5	E33
36.9000	1A3D70A4	-171.5000	860B60B6	266	9C1	0C3	161
35.2500	19111111	-172.5000	85555555	E00	000	C6F	7AB
33.6000	17E4B17E	65.7500	2EC16C17	99A	F30	81B	C44
31.8000	169D036A	-142.7500	9A7D27D2	4CD	2C7	363	91F
30.0000	15555555	59.5000	2A4FA4FA	000	6DE	EAB	439
28.0000	13E93E94	-60.0000	D5555555	AAB	555	96C	800
25.9000	126AF37C	-66.7000	D091A2B4	511	2E2	3EA	5D9
23.6000	10C83FB7	-120.0000	AAAAAAAB	EEF	000	DE2	555
21.1000	0F012345	41.5000	1D82D82E	844	572	754	39A
18.2000	0CF1357A	-144.0000	9999999A	089	99A	FB9	000
14.9000	0A987654	-121.0000	A9F49F4A	7BC	D77	712	2D8
10.5000	07777777	121.0000	560B60B6	C00	7E9	B89	289
5.1000	03A06D3A	6.2500	0471C71C	D9A	064	D60	01C
2.5000	01C71C72	154.2800	6DB5D120	6AB	48E	68E	DB3
0.0000	00000000	60.0000	2AAAAAAB	000	D55	000	AAB
0.0000	00000000	-157.5000	90000000	000	300	000	A00

2.4.17.4 Verification of TIS-B Message Processing and Report Generation (§2.2.17.4)

No specific test is required to validate §2.2.17.4.

2.4.17.4.1 Verification of TIS-B Message-to-Track Correlation (§2.2.17.4.1)

Appropriate tests for validating §2.2.17.4.1 are contained in §2.4.17.4.2, §2.4.17.4.3, §2.4.17.4.4, and §2.4.17.4.6.

2.4.17.4.1.1 Verification of TIS-B Messages Having a 24-Bit Address (§2.2.17.4.1.1)

Purpose/Introduction:

For a target that has a 24-bit address, that address is used for correlating new receptions with information in the track file. Correlation is successful if the address matches exactly. If the 24-bit address in a received message is either all ZEROs or all ONEs, it is considered to be illegal, and the message will be discarded. Otherwise, when a TIS-B Position Message having a 24-bit address is received, and an existing TIS-B track has the same address, the message will be correlated with the track as specified in §2.2.17.4.1.1.

Measurement Procedure:

Step 1: Verification of the Correlation of a Received TIS-B with an Existing TIS-B Track

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message containing an ICAO 24-bit address. Within two minutes, input another different TIS-B message with the same ICAO address as the previous message and verify that the position information in the second TIS-B position message is reflected in the output TIS-B Report.

Step 2: Verification of the correlation of a Received TIS-B with an Existing ADS-B Track

Set up to simulate ADS-B and TIS-B Transmitted Messages by inputting ADS-B and TIS-B Message information directly to the Receiving Subsystem. Input a simulated ADS-B position message containing an ICAO 24-bit address. Within two minutes, input a TIS-B message with a different position and the same ICAO address as the ADS-B message and verify that the position information in the TIS-B position message is reflected in the output TIS-B Report.

2.4.17.4.1.2 Verification of TIS-B Messages Having Mode A Code and Track Number (§2.2.17.4.1.2)

Purpose/Introduction:

For a target not identified by a 24-bit address, but instead having a Mode A code and a TIS-B track number, then these are used to correlate with information in the track file. Correlation is successful if the Mode A code and the track number both match exactly. When a TIS-B Message having a Mode A code and TIS-B track number is received, and an existing TIS-B track has the same Mode A code and ADS-B track number, the message will be correlated with the track as specified in §2.2.17.4.1.2.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message containing a 12-bit Mode A code followed by a 12-bit track file number. Within two minutes, input another different TIS-B position message with the same 12-bit Mode A code followed by the same 12-bit track file number as the previous message and verify that the position information in the second TIS-B position message is reflected in the output TIS-B Report.

2.4.17.4.2 Verification of TIS-B Position Message Decoding (§2.2.17.4.2)

Purpose/Introduction:

This test procedure verifies the requirements of TIS-B Position Message decoding as specified in §2.2.17.4.2.

Measurement Procedure:

Step 1: Verification of Global Decoding on the Reception of Even and Odd Formats Within 10 Seconds

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message with an “even” format. Within ten seconds, input another TIS-B position message with an “odd” format. Verify that a “Global” decode has occurred by ensuring that the input position information is reflected in the output TIS-B Report.

Step 2: Verification of Local Decoding, on Reception, When the Track is Complete

Input another simulated TIS-B position message within ten seconds of those in step 1 above. Verify that a “Local” decode has occurred by ensuring that the new input position information is reflected in the output TIS-B Report.

Step 3: Verification of the Storage of Track File Information

Wait more than ten seconds after step 2 above and input another TIS-B position message. Verify that this new input information is stored in the track file for later use and that it is not reflected in the output TIS-B Report.

Note: *It is not necessary to save any encoded positions longer than 10 seconds.*

2.4.17.4.3 Verification of TIS-B Track Update (§2.2.17.4.3)

Purpose/Introduction:

This test procedure verifies the requirements for TIS-B Track Update as specified in §2.2.17.4.3.

Measurement Procedure:

Step 1: Verification of Position and (TOA) Updates – Complete Track

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message with an "even" format. Within ten seconds, input another TIS-B position message with an "odd" format. This should create a Complete track. Again, within ten seconds, input another position message. This should trigger a local decode and update the data fields. Verify that this new position and its corresponding TOA are reflected in the output TIS-B Report.

Step 2: Verification of Incomplete to Complete Track Promotion and Data Storage

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message with an "even" format. This should create an Incomplete track. Within ten seconds, input another TIS-B position message with an "odd" format. This should trigger a global decode and Complete the track. Verify that the track has been promoted to Complete and that the latter input position and TOA are saved in the track.

Step 3: Verification of Data Storage When Global Decode Does Not Occur

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message with an "even" format. After more than ten seconds, input another position message. In this case a global decode should not occur. Verify that the track is still Incomplete and that the latter position and TOA are saved for possible future decodes.

2.4.17.4.4 Verification of TIS-B Track Initiation (§2.2.17.4.4)

Purpose/Introduction:

This test procedure verifies the requirements of the TIS-B Track Initiation as specified in §2.2.17.4.4.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message with an "even" format.

Verify that there is an Incomplete track created and that the position, TOA and even/odd bit are saved. Wait 125 seconds (to allow the first track to be dropped) and repeat this procedure with an "odd" formatted position message and verify the same parameters.

2.4.17.4.5 Verification of TIS-B Track Drop (§2.2.17.4.5)

Purpose/Introduction:

This test procedure verifies the requirements of TIS-B Track Drop as specified in §2.2.17.4.5.

Measurement Procedure:

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B position message with an "even" format. Within ten seconds, input another TIS-B position message with an "odd" format. This should create a Complete track.

Verify that 120 seconds after the "odd" position message is received, the position and TOA information are still saved in the track. Verify that 125 seconds after the "odd" position message is received, the position and TOA information are dropped (i.e.) the corresponding data fields are set to ALL ZEROs.

2.4.17.4.6 Verification of TIS-B Report Generation (§2.2.17.4.6)

Purpose/Introduction:

This test procedure verifies the requirements of TIS-B Report Generation as specified in §2.2.17.4.6.

Measurement Procedure:

Step 1: Verification of Non-Position Report Elements and Timing

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B message.

Verify that within 0.5 seconds of the receipt of this message that all of the non-position elements are reported directly as received. Repeat this step for each of the TIS-B message types.

Step 2: Verification of Position Report Elements and Timing

Set up to simulate TIS-B Transmitted Messages by inputting TIS-B Message information directly to the Receiving Subsystem. Input a simulated TIS-B message.

Verify that within 0.5 seconds of the receipt of this message that all of the position elements (latitude, longitude, altitude, address and TOA) are reported directly as well as all of the other information received, including all reserved fields for the TIS-B fine format messages (§2.2.17.3.1 to §2.2.17.3.4) and the entire message content (i.e., including the complete 88-bit content of the DF, CF, AA and ME fields of the Extended Squitter Message) of any received TIS-B Management

Message (Table 2-106, for CF=4). Repeat this step for each of the TIS-B message types.

2.4.18 Verification of the ADS-B Rebroadcast Service – Formats and Coding (§2.2.18)

2.4.18.1 Verification of the Introduction (§2.2.18.1)

No specific test procedure is required to validate §2.2.18.1.

2.4.18.2 Verification of the ADS-B Rebroadcast Format Definitions (§2.2.18.2)

Appropriate test procedures required to validate the transmission and reception of ADS-B Rebroadcast Messages are provided in the subparagraphs of §2.4.18.4 below.

2.4.18.3 Verification of the Control Field Allocations (§2.2.18.3)

Appropriate test procedures required to validate the transmission and reception of ADS-B Rebroadcast Messages are provided in the subparagraphs of §2.4.18.4 below.

2.4.18.4 Verification of the ADS-B Rebroadcast Surveillance Message Definitions (§2.2.18.4)

Purpose/Introduction:

The Rebroadcast of ADS-B information on the 1090 MHz Extended Squitter data link is accomplished by utilizing the same ADS-B Message formats defined in Figure A-1 through Figure A-10, with the exception of the need to transmit an indication to the 1090 MHz Receiving Subsystem as to the type of identity associated with the aircraft data being reported in the ADS-B Rebroadcast Message. This identification is performed using the ICAO/Mode A Flag (IMF), which was previously discussed in §2.2.17.3.1.2 for the TIS-B transmissions.

The insertion of this one bit into the 1090ES ADS-B Messages identified in the subparagraphs below allows the ADS-B Receiving Subsystem to interpret the Address Field (AF) in the following manner:

IMF = 0 indicates that the ADS-B Rebroadcast data is identified by an ICAO 24-bit Address.

IMF = 1 indicates that the ADS-B Rebroadcast data is identified by an anonymous 24-bit address or ground vehicle address or fixed obstruction address.

Measurement Procedure:

Appropriate test procedures required to validate the transmission and reception of ADS-B Rebroadcast Messages are provided in §2.4.18.4.1 through §2.4.18.4.7 below.

2.4.18.4.1 Verification of the Rebroadcast of ADS-B Airborne Position Messages (§2.2.18.4.1)

Purpose/Introduction:

These test procedures verify that the ME Field of the Rebroadcast Airborne Position Message is formatted as specified in Figure 2-3, **except** that ME bit 8 is redefined to be the ICAO/Mode A Flag (IMF).

Measurement Procedure:

Step 1: Establish Initial Conditions

Configure the ADS-B test equipment to transmit Airborne Position Messages by providing position information at the nominal rate. Ensure the transmission of an ADS-N Aircraft Operational Status Message to ensure receipt of the Version Number. Ensure that the ADS-B test equipment provides a known value of Latitude and Longitude position data from the Navigation source and that it outputs encoded Latitude and Longitude data for the Airborne Position Message in accordance with the CPR Format described in Appendix A. Format the Airborne Position Message with both DF=18 and CF=4, and DF=18 and CF=6.

Step 2: Valid Message Contents When Selecting ICAO 24-Bit Address

Input an IMF value of ZERO (0) into ME Bit 8 of the Airborne Position Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address Qualifier input to the ADS-B test equipment. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 4 or 6 as appropriate
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals 9 to 18 or 20 to 22
IMF field (Message Bit 40) equals ZERO (0)
Lat/Lon fields equal transmitted Lat/Lon

Verify that the remaining fields of the ADS-R Airborne Position Message, that is received and decoded, was encoded in the proper format, i.e., "***odd***" and "***even***" encoding, by correlating the received Message to the stimulus data provided by the test equipment.

Step 3: Valid Message Contents When Selecting Anonymous Address

Input an IMF value of ONE (1) into ME Bit 8 of the Airborne Position Message to be transmitted. Input 555555 {HEX} for the Anonymous Address. Select "Anonymous Address" at the Address Qualifier input to the ADS-B test equipment. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 4 or 6, as appropriate
AA field (Message Bits 9 – 32) equals 555555 {HEX}
TYPE Code field (Message Bits 33 – 37) equals 9 to 18 or 20 to 22
IMF field (Message Bit 40) equals ONE (1)
Lat/Lon fields equal transmitted Lat/Lon

Verify that the remaining fields of the ADS-R Airborne Position Message, that is received and decoded, was encoded in the proper format, i.e., "***odd***" and "***even***" encoding, by correlating the received Message to the stimulus data provided by the test equipment.

2.4.18.4.2 Verification of the Rebroadcast of ADS-B Surface Position Messages (§2.2.18.4.2)

Purpose/Introduction:

These test procedures verify that the ME Field of the Rebroadcast Surface Position Message is formatted as specified in Figure 2-5, **except** that ME bit 21 is redefined to be the ICAO/Mode A Flag (IMF).

Measurement Procedure:

Step 1: Establish Initial Conditions

Configure the ADS-B test equipment to transmit Surface Position Messages by providing position information at the nominal rate. Ensure that the ADS-B test equipment provides a known value of Latitude and Longitude position data from the Navigation source and that it outputs encoded Latitude and Longitude data for the Surface Position Message in accordance with the CPR Format described in Appendix A. Format the Surface Position Message with both DF=18 and CF=4 and DF=18 and CF=6.

Step 2: Valid Message Contents When Selecting ICAO 24-Bit Address

Input an IMF value of ZERO (0) into ME Bit 21 of the Surface Position Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address Qualifier input to the ADS-B test equipment. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 4 or 6, as appropriate
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 5 to 8
IMF field (Message Bit 53) equals ZERO (0)
Lat/Lon fields equal transmitted Lat/Lon

Verify that the remaining fields of the ADS-R Surface Position Message, that is received and decoded, was encoded in the proper format, i.e., "***odd***" and "***even***" encoding, by correlating the received Message to the stimulus data provided by the test equipment.

Step 3: Valid Message Contents When Selecting Anonymous Address

Input an IMF value of ONE (1) into ME Bit 8 of the Surface Position Message to be transmitted. Input 555555 {HEX} for the Anonymous Address. Select "Anonymous Address" at the Address Qualifier input to the ADS-B test equipment. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 4 or 6, as appropriate
AA field (Message Bits 9 – 32) equals 555555 {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 5 to 8
IMF field (Message Bit 53) equals ONE (1)
Lat/Lon fields equal transmitted Lat/Lon

Verify that the remaining fields of the ADS-R Surface Position Message, that is received and decoded, was encoded in the proper format, i.e., "***odd***" and "***even***" encoding, by correlating the received Message to the stimulus data provided by the test equipment.

2.4.18.4.3 Verification of the Rebroadcast of ADS-B Aircraft Identification and Category Messages (§2.2.18.4.3)

Purpose/Introduction:

This test procedure verifies that the ME Field of the Rebroadcast Aircraft Identification and Category Message is formatted exactly as specified in Figure 2-6.

Note: *Any Rebroadcast Aircraft Identification and Category Message does not contain the IMF bit since aircraft using an anonymous 24-bit address will not provide identity and category information.*

Measurement Procedure:

The test procedures provided in §2.4.3.2.5 and its subparagraphs **shall** be used to validate the transmission and reception of Rebroadcast Aircraft Identification and Category Messages.

2.4.18.4.4 Verification of the Rebroadcast of ADS-B Airborne Velocity Messages (§2.2.18.4.4)

Purpose/Introduction:

These test procedures verify that the ME Field of the Rebroadcast Airborne Velocity Messages is formatted as specified in Figure 2-7 for Subtype 1 & 2 Messages, and in Figure 2-8 for Subtype 3 & 4 Messages, **except** that ME bit 9 is redefined to be the ICAO/Mode A Flag (IMF).

Measurement Procedure:

Step 1: Establish Initial Conditions

Configure the ADS-B test equipment to transmit Version ONE (1) and TWO (2) Airborne Velocity Messages by providing velocity information at the nominal update rate. Provide the data externally at the interface to the ADS-B test equipment. Set up the system to enable broadcast of Airborne Velocity Messages (see additional information in §2.2.3.3.2.5). Set the ADS-B test equipment to Airborne status.

Step 2: Verification of Subtype 1 Messages with ICAO 24-Bit Address

Provide velocity information in the form of Velocity Over Ground (i.e., Ground Speed) with a valid value that is greater than ZERO, but non-supersonic (i.e., both North/South and East/West Velocity inputs are less than 1000 knots). Input an IMF value of ZERO (0) into ME Bit 9 of the Airborne Velocity Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address Qualifier input to the ADS-B test equipment. Verify the following ADS-R Airborne Velocity Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 19
Subtype Code field (Message Bits 38 – 40) equals decimal 1
IMF field (Message Bit 41) equals ZERO (0)
Decoded N/S and E/W Velocity values equal transmitted values

Verify the remaining fields of the ADS-R Airborne Velocity Message, by correlating the decoded Message to the stimulus data provided by the test equipment, being sure to match the data format to the correct Version Number.

Step 3: Verification of Subtype 2 Messages with ICAO 24-Bit Address

Repeat the same setup as in Step 2 above. Increase the North/South velocity to 1050 knots. Verify the following ADS-R Airborne Velocity Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 19
Subtype Code field (Message Bits 38 – 40) equals decimal 2
IMF field (Message Bit 41) equals ZERO (0)
Decoded N/S and E/W Velocity values equal transmitted values

Verify the remaining fields of the ADS-R Airborne Velocity Message, by correlating the decoded Message to the stimulus data provided by the test equipment, being sure to match the data format to the correct Version Number.

Step 4: Verification of Subtype 3 Messages with ICAO 24-Bit Address

Provide velocity information in the form of Airspeed and Heading information with a valid Airspeed value that is greater than ZERO, but non-supersonic (i.e., the Airspeed input is less than 1000 knots). Input an IMF value of ZERO (0) into ME Bit 9 of the Airborne Velocity Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address Qualifier input to the ADS-B test equipment. Verify the following ADS-R Airborne Velocity Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 19
Subtype Code field (Message Bits 38 – 40) equals decimal 3
IMF field (Message Bit 41) equals ZERO (0)
Decoded Airspeed Velocity value equals transmitted value

Verify the remaining fields of the ADS-R Airborne Velocity Message, by correlating the decoded Message to the stimulus data provided by the test equipment, being sure to match the data format to the correct Version Number.

Step 5: Verification of Subtype 4 Messages with ICAO 24-Bit Address

Repeat the same setup as in Step 4 above. Increase the Airspeed velocity to 1050 knots. Verify the following ADS-R Airborne Velocity Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 19
Subtype Code field (Message Bits 38 – 40) equals decimal 4
IMF field (Message Bit 41) equals ZERO (0)
Decoded Airspeed Velocity value equals transmitted value

Verify the remaining fields of the ADS-R Airborne Velocity Message, by correlating the decoded Message to the stimulus data provided by the test equipment, being sure to match the data format to the correct Version Number.

Step 6: Verification of Airborne Velocity Messages with Anonymous Addresses

Repeat the setups of Steps 2, 3, 4 and 5, respectively, except that the input for the Address shall be 555555 {HEX} for the Anonymous Address. Select "Anonymous Address" at the Address Qualifier input to the ADS-B test equipment for each respective Test Step. Input an IMF value of ONE (1) into ME Bit 9 of each respective Airborne Velocity Message to be transmitted. Verify that the content of the ADS-R Airborne Velocity Message upon decode of the transmitted data matches those outputs defined in Steps 2, 3, 4 and 5, respectively, except that the AA field (Message Bits 9 – 32) equals 555555 {HEX}, and the IMF field (Message Bit 41) equals ONE (1), in each case, being sure to match the data format to the correct Version Number.

2.4.18.4.5 Verification of the Rebroadcast of ADS-B Aircraft Emergency/Priority Status Messages (§2.2.18.4.5)

Purpose/Introduction:

These test procedures verify that the ME Field of the Rebroadcast Aircraft Emergency/Priority Status Message is formatted as specified in Figure 2-13, **except** that ME bit 56 is redefined to be the ICAO/Mode A Flag (IMF).

Measurement Procedure:

Step 1: Establish Initial Conditions

Perform set up of the unit under test as specified in the Test Procedure in §2.4.3.2.7.8.

Step 2: Valid Message Contents When Selecting ICAO 24-Bit Address

Input an IMF value of ZERO (0) into ME Bit 56 of the Aircraft Emergency/Priority Status Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address

Qualifier input to the ADS-B Transmitting Subsystem. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 28
Subtype Code field (Message Bits 38 – 40) equals decimal 1
IMF field (Message Bit 88) equals ZERO (0)

Verify the remaining fields of the ADS-R Aircraft Emergency/Priority Status Message, by correlating the decoded Message to the stimulus data provided by the test equipment.

Step 3: Valid Message Contents When Selecting Anonymous Address

Reinitialize the unit under test as in Step 1 above. Input an IMF value of ONE (1) into ME Bit 56 of the Aircraft Emergency/Priority Status Message to be transmitted. Input 555555 {HEX} for the Anonymous Address. Select "Anonymous Address" at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals 555555 {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 28
Subtype Code field (Message Bits 38 – 40) equals decimal 1
IMF field (Message Bit 88) equals ONE (1)

Verify the remaining fields of the ADS-R Aircraft Emergency/Priority Status Message, by correlating the decoded Message to the stimulus data provided by the test equipment.

2.4.18.4.6 Verification of the Rebroadcast of ADS-B Target State and Status Messages (§2.2.18.4.6)

Purpose/Introduction:

These test procedures verify that the ME Field of the Rebroadcast Target State and Status Message is formatted as specified in Figure 2-10, **except** that ME bit 51 is redefined to be the ICAO/Mode A Flag (IMF).

Measurement Procedure:

Step 1: Establish Initial Conditions

Configure the ADS-B Transmitting Subsystem to transmit Target State and Status Messages by providing valid trajectory information at the nominal rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status.

Step 2: Valid Message Contents When Selecting ICAO 24-Bit Address

Input an IMF value of ZERO (0) into ME Bit 51 of the Target State and Status Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select "ICAO 24-Bit Address" at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 29
Subtype Code field (Message Bits 38 – 40) equals decimal 0
IMF field (Message Bit 83) equals ZERO (0)

Verify the remaining fields of the ADS-R Target State and Status Message, by correlating the decoded Message to the stimulus data provided by the test equipment.

Step 3: Valid Message Contents When Selecting Anonymous Address

Reinitialize the unit under test as in Step 1 above. Input an IMF value of ONE (1) into ME Bit 51 of the Target State and Status Message to be transmitted. Input 555555 {HEX} for the Anonymous Address. Select "Anonymous Address" at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals 555555 {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 29
Subtype Code field (Message Bits 38 – 40) equals decimal 0
IMF field (Message Bit 83) equals ONE (1)

Verify the remaining fields of the ADS-R Target State and Status Message, by correlating the decoded Message to the stimulus data provided by the test equipment.

2.4.18.4.7 Verification of the Rebroadcast of ADS-B Aircraft Operational Status Messages (§2.2.18.4.7)

Purpose/Introduction:

These test procedures verify that the ME Field of the Rebroadcast Aircraft Operational Status Message is formatted as specified in Figure 2-11, **except** that ME bit 56 is redefined to be the ICAO/Mode A Flag (IMF).

Measurement Procedure:

Step 1: Establish Initial Conditions

Configure the ADS-B Transmitting Subsystem to transmit Aircraft Operational Status Messages by providing valid trajectory information at the nominal rate. Provide the data externally at the interface to the ADS-B system. Set the ADS-B Transmitting Subsystem to Airborne status.

Step 2: Valid Message Contents When Selecting ICAO 24-Bit Address

Input an IMF value of ZERO (0) into ME Bit 56 of the Aircraft Operational Status Message to be transmitted. Input AAAAAA {HEX} for the ICAO 24-Bit Address. Select “ICAO 24-Bit Address” at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals AAAAAA {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 31
Subtype Code field (Message Bits 38 – 40) equals decimal 0
IMF field (Message Bit 88) equals ZERO (0)

Verify the remaining fields of the ADS-R Aircraft Operational Status Message, by correlating the decoded Message to the stimulus data provided by the test equipment.

Repeat this step after setting the ADS-B Transmitting Subsystem to the “On-Ground” status. Verify that the only difference in the decoded output of the Message from those specified above is that Message Bits 38 – 40 are set to ONE (1) in the output of the Aircraft Operational Status Message.

Step 3: Valid Message Contents When Selecting Anonymous Address

Reinitialize the unit under test as in Step 1 above. Input an IMF value of ONE (1) into ME Bit 56 of the Aircraft Operational Status Message to be transmitted. Input 555555 {HEX} for the Anonymous Address. Select “Anonymous Address” at the Address Qualifier input to the ADS-B Transmitting Subsystem. Verify the following ADS-R Message content upon decode of the transmitted data:

DF field (Message Bits 1 – 5) equals decimal 18
CF field (Message Bits 6 – 8) equals decimal 6
AA field (Message Bits 9 – 32) equals 555555 {HEX}
TYPE Code field (Message Bits 33 – 37) equals decimal 31
Subtype Code field (Message Bits 38 – 40) equals decimal 0
IMF field (Message Bit 88) equals ONE (1)

Verify the remaining fields of the ADS-R Aircraft Operational Status Message, by correlating the decoded Message to the stimulus data provided by the test equipment.

Repeat this step after setting the ADS-B Transmitting Subsystem to the "On-Ground" status. Verify that the only difference in the decoded output of the Message from those specified above is that Message Bits 38 – 40 are set to ONE (1) in the output of the Aircraft Operational Status Message.

3.0 Installed Equipment Performance

This section states the minimum acceptable level of performance for the equipment when installed in the aircraft. Installed performance requirements are the same as contained in section §2.2, which are verified through bench and environmental testing. Some system attributes and performance aspects may be affected by the physical installation (e.g. antenna patterns can affect system transmit and receive performance). System integrators might have several options when connecting to aircraft sensors or data sources. Some sources might lack the necessary range, resolution or accuracy to support the desired applications. This section identifies system attributes which installation techniques and choices might affect, beyond the equipment manufacturer's ability to compensate.

Note: *Installation of Non-Transponder-Based 1090 MHz ADS-B equipment in airplanes equipped with Mode-S transponders is prohibited. The transmission of squitters in addition to TCAS interrogation responses contributes unnecessary RF energy to the spectral environment. TCAS systems (in other airplanes) cannot take advantage of hybrid surveillance on the ADS-B data, since the non-transponder data cannot be validated by TCAS interrogation. ADS-B data is not directly available to ground interrogators as when read from transponder registers.*

3.1 Installed Equipment Considerations

A complete ADS-B system consists of five (5) functional elements:

1. Data sources for aircraft position, velocity, flight plan, status, etc.
2. ADS-B transmitter
3. ADS-B receiver
4. Report Generator
5. Applications

Each of these elements must meet the minimum requirements for an application in order for operational approval to be granted for that application. Table 3-1 is an example of a system that meets the minimum requirements for 3 generic applications. Additional guidance for determining requirements is contained in following paragraphs.

Table 3-1: Example System

Application	Data Source	ADS-B Equipment Class
VFR (e.g. Aid to Visual Acquisition)	VFR GPS (AC20-138 Compliant)	A0/Type 1 (*see Note*)
IFR (e.g. Aid to Terminal Separation and Sequencing)	TSO C129a, Class A2 GPS Receiver	A2/Type 1 (*see Note*)
Special IFR (e.g. Closely Spaced Parallel Approaches)	TSO C129a, Class A1S/A1 GPS Receiver	A3/Type 2 (*see Note*)

Note: *The type designation refers to the Receiver Report Generator type and is included here as an example of equipment labeling and is not to imply any specific interface is required. The developer is free to choose any of the interface types so long as it is properly documented and meets the end-to-end system requirements.*

3.1.1 Data Sources

Data sources necessary to support an application **shall** meet the requirements of the operational environment (e.g. The source of ADS-B navigation data must be approved for IFR navigation if the ADS-B application is to be approved for IFR operations.), and **shall** meet the accuracy, range, and resolution requirements of the appropriate ADS-B equipage category.

3.1.2 ADS-B Transmit Power

The Transmit Power requirement (i.e, Effective Radiated Power) is different for different classes of equipment because of differences in altitude capabilities and ranges of applications. The classes are defined in §2.1.12 and the power level in each class is defined in §2.2.2.

Different classes of equipment have different minimum message capability requirements. Transmitted message capability requirements for Class A and Class B transmitters are defined in §2.1.12.1. Some applications may require support for specific On-Condition Messages.

3.1.3 ADS-B Receiver

The receiver **shall** be capable of supporting the message types required by application.

The receiver sensitivity limits the expected range of the installed system. The sensitivity of the installed receiving equipment should be appropriate to the minimum range requirement for the ADS-B equipage class. Receivers having a Minimum Trigger Level (MTL) of –74 dBm are intended to support applications at ranges up to 20 nautical miles. Receivers having a MTL of –79 dBm are intended to support applications at ranges up to 40 nautical miles. Receivers having a MTL of –84 dBm are intended to support applications at ranges up to 90 nautical miles.

3.1.4 Report Generator

The report generator function **shall** be capable of accepting all message types and generating all reports appropriate to the intended applications. Special attention may be necessary for Type 1 interfaces to ensure that the equipment is properly matched to the application requirements.

3.1.5 Applications

Applications comprise any use of ADS-B data. Applications **shall** be developed in accordance with approved standards if standards exist. If approved standards do not exist, the developer **shall** propose a standard early in the development process to support approval of the operational concept and identify operational limitations.

First time operational approval for the use of installed ADS-B equipment in a given application will be accomplished via the Type Certificate (TC) or Supplemental Type Certificate (STC) approval process. Subsequent installations may be approved via the TC, STC, or field approval process. It is incumbent upon the developer to show that the system meets the requirements of the application. Operating limits of the system **shall** be included in an approved aircraft/rotorcraft flight manual supplement (AFMS/RFMS).

3.2 Equipment Installation

3.2.1 Aircraft Environment

Equipment **shall** be installed such that environmental conditions do not exceed the manufacturer's specifications during normal operations.

3.2.2 Aircraft Power Source

The supply voltage and allowable variation **shall** not exceed the manufacturer's specifications during normal operations. Equipment voltage and frequency tolerance characteristics **shall** be compatible with an aircraft power source of appropriate category as specified in RTCA DO-160F (EUROCAE, ED-14F).

3.2.2.1 Power Fluctuation

The equipment **shall** retain memory of variable data through aircraft power transfer, which occurs during normal operation. Typical power transfer involves switching from external power to internal power, either battery or APU generator, or to engine driven generator(s). The equipment **shall** not require re-initialization for power transfer (i.e. power loss) for a period up to 0.5 second maximum. Power transfer **shall** not latch a failure indication. Momentary failure indications, during switching, are allowed.

3.2.3 Accessibility

Controls, indicators, and displays provided for in-flight use **shall** be readily accessible and/or readable from the pilot's normal seated position. If two pilots are required to operate the aircraft, the controls must be readily accessible from each pilot's seated position. Adequate protection must be provided to prevent inadvertent turnoff of the equipment.

3.2.4 Display Visibility

If there is a control panel display, then appropriate flight crew member(s) must have an unobstructed view of displayed data when in the seated position. The brightness of any display must be adjustable to levels suitable for data interpretation under all cockpit ambient lighting conditions ranging from total darkness to reflected sunlight.

Note: *Visors, glare shields or filters may be an acceptable means of obtaining daylight visibility.*

3.2.5 Indicators

If visual indicators are installed, they **shall** be visible and readable from the pilot's normal seated position. If two pilots are required to operate the aircraft, indicators **shall** be visible from each pilot's seated position. The brightness of any indicator must be adjustable to levels suitable under all cockpit ambient lighting conditions ranging from total darkness to reflected sunlight. If an indication is distracting, a means to cancel it should be provided. If the optional Extended Squitter Inhibit capability per §2.1.5.1 is provided, the indication when activated **shall** be annunciated to the pilot.

3.2.6 Alerts

If appropriate to an application, a means to alert the crew **shall** be provided. Aural alerts **shall** provide a mechanism by which they can be prioritized with respect to other aircraft system alerts (e.g. audio inhibit input and output discretes). Aural alerts **shall** include a means by which they can be silenced.

3.2.7 Failure Protection

Probable failures of the ADS-B equipment must not degrade the normal operation of equipment or systems connected to it. The failure of connected equipment or systems must not degrade normal operation of the ADS-B equipment except for loss of functions that are directly dependent upon the failed equipment.

3.2.8 Failure Indication

The ADS-B system operational status **shall** be available to the crew. Failures of the ADS-B transmitter and receiver **shall** be annunciated to the crew. Though acceptable, dedicated ADS-B transmit and receive failure indicators are not required. Text messages, displayed to the crew until acknowledged, are acceptable. Systems which combine transmit and receive functions in a common unit may use a single annunciation to indicate a failure. When an ADS-B function is hosted in another system, the host system failure annunciation is adequate to indicate loss of ADS-B function (e.g. If the transponder also transmits ADS-B squitters, loss of ADS-B transmission is logically assumed with a TRANSPONDER FAIL indication.). Otherwise, transmitter and receiver failure warnings **shall** be independent (§2.2.11.5).

3.2.9 Interference Effects

The equipment **shall** not be the source of objectionable conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft. If these systems are installed, check for interference when operating on TACAN channels 60 to 72; DME channels 65 to 67 (1089 - 1091 MHz paired with VHF frequency 133.8 to 134.05)

Note: *Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. The installing facility is responsible for resolving incompatibilities between the ADS-B equipment and previously installed equipment in the aircraft.*

3.3 Antenna Installation

3.3.1 General Considerations

Antenna gain and pattern characteristics are major contributors to the system data link performance. The location and number of antennas required for aircraft ADS-B systems is determined by the equipage class. Class A1, A2, and A3 equipment require antenna diversity and **shall** have transmitting and receiving capability on both the top and bottom of the aircraft. Class B1 equipment requires antenna diversity and **shall** have transmitting capability on both the top and bottom of the aircraft. Diverse use of the installed antennas **shall** comply with the requirements of §2.2.13.6 and may be demonstrated by analysis.

Class A0, A1S, B0 and B1S antenna gain pattern performance **shall** be shown at least equivalent to that of a quarter-wave resonant antenna mounted on the fuselage bottom surface.

If the ADS-B transmitter function is hosted in a Mode-S transponder, the antennas **shall** comply with the requirements of RTCA DO-181D (EUROCAE ED-73C).

If the ADS-B receiver function is hosted in a TCAS computer, the antennas **shall** comply with the requirements of RTCA DO-185B (EUROCAE ED-143).

3.3.2 Transmission Lines

Transmission lines to the antennas **shall** have impedance, power handling, and loss characteristics in accordance with the equipment manufacturer's specifications. The VSWR, as seen through the transmission lines to the antenna(s), **shall** be within the limits specified by the manufacturer.

When a transmission line is included as a part of the installation, all minimum installed system performance requirements stated in section §2.2, must be met. Test results provided by the equipment manufacturer may be accepted in lieu of tests performed by the equipment installer.

3.3.3 Antenna Location

Antennas **shall** be mounted as near as practical to the center line of the fuselage. Antennas **shall** be located to minimize obstruction to their fields in the horizontal plane.

Note: *Where possible, it is recommended that the antennas be mounted on the forward part of the fuselage, thereby minimizing blockage due to the vertical stabilizer and engine nacelles.*

3.3.3.1 Minimum Distance from Other Antennas

The spacing between any ADS-B antenna and any transponder (Mode-S or ATCRBS) antenna **shall** be sufficient to provide a minimum of 20dB of isolation between the two antennas.

Note: *If both antennas are conventional omni-directional matched quarter-wave stubs, 20 dB of isolation is obtained by providing a spacing of at least 51 cm (20 in.) between the centers of the two antennas. If either antenna is other than a conventional stub, the minimum spacing must be determined by measurement.*

3.3.3.2 Mutual Suppression

If other equipment installed in the aircraft operates at or near 1090 MHz, such as DME, the need for mutual suppression **shall** be determined. When mutual suppression is used, the requirements of §2.2.12 **shall** be met. There **shall** be no more than one active 1090 MHz transmitter per aircraft at any time.

3.3.4 Antenna Gain Performance

Gain performance of the ADS-B antenna(s) is tested to verify that the installed antenna gain is not degraded from §2.2.13 requirements, beyond an acceptable value. Transmit antenna(s) **shall** be located such that a receiving system reliably receives data from the transmitting aircraft at the minimum range appropriate to the equipage category, as stated in Table 3-2. Receive antenna(s) **shall** be located such that a receiving system reliably receives data from a transmitting aircraft at the minimum range appropriate to the equipage category, as stated in Table 3-2. If a traffic display is installed, reliable data reception is indicated by traffic target acquisition range and smooth movement of traffic targets, without excessive "pop-up," "drop-out," or position "jumps."

Note: *Typical ADS-B antennas have areas of reduced gain, directly above or below the antenna, such that no signal can be received from transmitters in the "cone of silence" or "uncertainty cone." Reliable data reception from these areas is not required. Approval of operational applications should consider this limitation.*

Table 3-2: Minimum Ranges for Receiving Reliability

Equipage		Required Range (NM)
Class	**Type**	
A0	Minimum	10
A1S/A1	Basic	20
A2	Enhanced	40
A3	Extended	90*
A3+	Extended Desired	120*

***** *For each equipage class, the value shown in Table 3-2 corresponds to forward directional coverage. Port and starboard coverage may be one half of this value; aft may be one third of this value. (Ref. RTCA DO-242A Table 3-2(a))*

3.3.4.1 Gain Performance Verification

Gain performance can be verified using one or a combination of four distinct procedures:

(a) full scale antenna range measurements,

(b) scaled model measurements,

(c) theoretical calculations,

(d) distance-area calculations, to ensure that the location of the antenna on the aircraft does not unduly degrade its gain performance.

This procedure(s) **shall** be performed on final installed equipment with all appropriate connections and antenna in order to demonstrate proper operation of the final installation.

3.3.4.1.1 Success Criteria

At an elevation angle of zero degrees relative to the fuselage reference plane, the gain of the forward ±45 degree azimuth sector of both the top and bottom antennas **shall** be no more than one dB below the gain of the antenna when installed on a standard ground plane as specified in §2.2.13. The radiation pattern gain, at zero degrees elevation, **shall** be within 3 dB of the gain of the ground-plane-installed antenna over 90% of the remainder of its azimuth coverage. The verification procedures of §2.4.13.1 through §2.4.13.5 **shall** be performed on final installed equipment with all appropriate connections and antenna in order to demonstrate proper operation of the final installation.

Note: *Antenna system performance tests are specified to accommodate the most stringent envisioned applications. Operational approval of proposed applications must consider installed antenna system performance. Installations that do not fully comply with the above requirements may be approved for particular operations based on the safety implications of the application.*

3.3.4.2 Full Scale Anechoic Antenna Range Measurements of Gain

The gain characteristics of the antenna as mounted on the actual airframe may be measured directly in a calibrated anechoic antenna test range using standard controlled procedures for such measurements. Gain characteristics determined in this way require no further validation.

Note: *Anechoic range measurements are generally impractical for determining full antenna gain patterns for large aircraft. However, such techniques may be practical for qualifying certain sub-regions of the coverage pattern or for validating model measurements or theoretical calculations.*

3.3.4.3 Scaled Model Measurements of Gain

Aircraft models for antenna measurements are normally 1/10 to 1/40 scale. Scale selection is dependent upon considerations such as availability of equipment, and antenna scaling, with larger models resulting in greater accuracy.

Only the major structural features of the airframe need be constructed. Details such as windows, doors, turbines, etc. are not required. The outside skin should be of conductive material. Typically, the fuselage and engine nacelles are modeled from metal tubing and/or shaped metal screening; wings and stabilizers can be modeled from flat metal plates. Movable control surfaces are not required unless they will have significant effects upon the antenna pattern.

Notes:

1. *In general, obstructions that subtend angles at the antenna of less than a few degrees in elevation or azimuth need not be modeled. However, smaller obstructions such as other antennas, that are located within a few wavelengths of the antenna under test, may have to be modeled because they can act as resonant scatterers and could have a significant effect on the radiation pattern.*

2. *If the swept area of propeller blades exceeds the limits given in (1) above, the blades can be worst-case modeled by a flat metal disk of radius proportional to blade length. If the radiation pattern using disks for propellers satisfies the success criteria, it can be assumed that the pattern modulation caused by the rotating blades will not significantly degrade the ADS-B system performance.*

3.3.4.4 Model Tests

Mount the scaled model antenna in the center of a ground plane whose radius is equal in wavelengths to the ground plane used for testing the full scale antenna.

Using a calibrated anechoic antenna test range, confirm that the gain of the scaled antenna (including possible multiple radiating elements, splitting or combining networks, impedance, and mutual coupling effects) is within 2 dB of the full-scale antenna gain, for all azimuth and elevation angles for which the gain of the full-scale antenna is within 6 dB of the peak gain.

Mount the scaled model antenna on the aircraft model at the intended installation location.

Measure the antenna gain for all azimuth angles (for top and bottom antennas).

Confirm that the scaled antenna meets the success criteria of §3.3.4.1.1 above.

3.3.4.5 Theoretical Calculations of Antenna Gain

The gain characteristics of the antenna as mounted on the actual airframe may be determined by a combination of radiation pattern calculations, and measurements designed to validate those calculations. When using such techniques to determine the gain of a multi-element antenna, it is necessary to show that the calculations include the inherent characteristics of the antenna elements and their drivers, splitters, or combining networks and any effects due to mutual coupling between those elements.

3.3.4.5.1 Validation of Theoretical Calculations

If radiation pattern calculations are used to prove the success criteria of §3.3.4.1.1 above, the manufacturer of the antenna must provide corroborating data demonstrating the success of the calculation technique in predicting the antenna gain on an airframe roughly similar in size and complexity to the airframe under qualification. Such data must be obtained by comparison with selected gain measurements made

(a) on a full-size airframe using a calibrated ramp test antenna range, or

(b) on a scaled model airframe as indicated in 3.3.4.4.

3.3.4.5.2 Distance Area Calculations

The extent to which the antenna installation minimizes obstructions in the horizontal plane and minimizes effects of reflecting objects, may be judged by the distance to such objects and their sizes. If the distances and sizes satisfy the condition given here, then the antenna installation may be considered validated with regard to antenna gain. The condition is: For target aircraft at zero degree elevation angle and at azimuth bearing between –90 degrees and +90 degrees,

$$\frac{A_1^2}{\lambda^2 D_1^2} + \sum \frac{A_2^2 G_2{}^{l}}{\lambda^2 D_2^2 G_2} + \sum \frac{A_3 G_3{}^{l}}{4\pi D_3^2 G_3} < 0.02$$

where $\lambda = 0.9$ ft. is the free space wavelength at 1090 MHz. The first term is applicable only if there is a metallic obstruction between the target and the ADS-B antenna. The distance in feet to the obstruction is denoted D_1 and the area in ft^2 of the obstruction projected in the direction of the ADS-B antenna is denoted A_1. The second term is a summation over flat metallic reflectors, if any, that are oriented so as to cause a specular reflection between the ADS-B antenna and the target. The distance to the reflector, in feet, is denoted D_2, the area, in square feet, of the reflector, projected in the direction of the ADS-B antenna is denoted A_2, the antenna gain in the direction of the reflector is denoted G'_2 and is dimensionless (i.e. gain in dB = 10 log G'_2), and the antenna gain in the direction of the target is denoted G_2 and is dimensionless. The third term is a summation over all other metallic objects that may cause reflections between the ADS-B antenna and the target. The parameters D_3, A_3, G'_3, and G_3 have the same meanings as in the second term. In the case of other aircraft antennas in view of the ADS-B antenna, a minimum value for A = 0.22 square feet is to be used if the actual area of the antenna is less than 0.22 square feet.

3.3.4.5.3 Dynamic Response

The antenna(s) **shall** be located such that operation of the equipment is not adversely affected by aircraft maneuvering or changes in attitude encountered in normal flight operations.

Note: *Class A0 and A1S installations are not required to install multiple (e.g., top fuselage and bottom fuselage) antennas.*

3.3.4.6 Installed Equipment Antenna System

3.3.4.6.1 Verification of Transmit Pattern Gain (§2.2.13.1)

Purpose/Introduction:

The purpose of this procedure is to verify that the gain of an omni-directional transmit antenna is not less than the gain of a matched quarter-wave stub minus 3 dB over 90 percent of a coverage volume from 0 to 360 degrees in azimuth and from 5 to 30 degrees above the ground plane when installed at center of 1.2 meter (4 feet) diameter (or larger) flat circular ground plane.

This procedure should be performed in the laboratory environment to demonstrate that the ADS-B Transmitting Subsystem properly delivers RF ADS-B Messages to the free space medium via the expected installation connections and radiating antenna.

This procedure **shall** be performed on final installed equipment with all appropriate connections and antenna in order to demonstrate proper operation of the final installation.

Equipment Required:

Provide a method of generating ADS-B Airborne Position Broadcast.

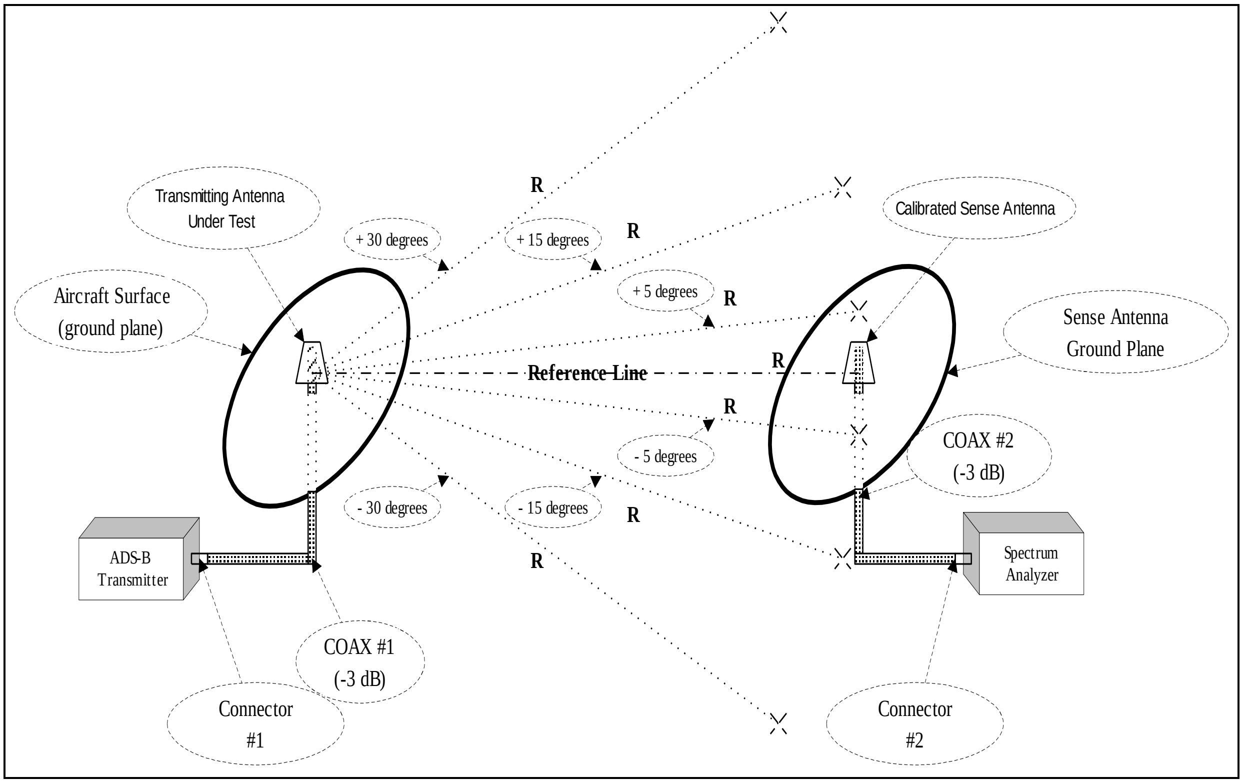
Calibrated quarter-wave stub Sense Antenna of known gain. (See Figure 3-1)

Appropriate Couplers and Connectors as required

Coaxial Connection of known attenuation (shown in Figure 3-1 as Coax #2)

Appropriate Attenuators as required

HP 8753E Spectrum Analyzer (or equivalent capability)



<u>Figure 3-1</u>: Antenna Test Configuration - 1

<u>Measurement Procedure:</u>

<u>Step 1:</u> <u>Understand the Equation</u>

<u>Define:</u>

P_out = Transmitted Power (**in watts**) Measured at the ADS-B Broadcast Message Generator output connector in watts

Loss_TX = **attenuation** (**in dB**) provided by connection of the ADS-B Broadcast Message Generator to the Transmitting Antenna. This includes the cable (i.e., Coax #1 in Figure 3-1) and connectors

G_tx = gain (**in dB**) of the transmitting antenna

R = Distance between the transmitting antenna and the receiving antenna in meters

Path_Loss = attenuation (**in -dB**) of a 1090 MHz signal in free space for distance = R

= $[\lambda/(4\pi R)]^2 = [(300/1090)/(4\pi R)]^2 = [(2.19020564 \text{ X } 10^{-2})/R]^2$

= $20*\log(2.19020564 \text{ X } 10^{-2}) - 20*\log(R)$

= $- 33.1903022 - 20*\log(R)$

G_rx = gain (**in dB**) of the receiving or Calibrated Sense Antenna

Loss_RX = **attenuation** (**in dB**) provided by connection of the Calibrated Sense

Antenna to the Spectrum Analyzer. This includes the cable (i.e., Coax #2 in Figure 3-1) and connectors and should be calibrated to 3 dB

P_rx_dBw = Power (in **dBw**) received at the Spectrum Analyzer

P_rx_dBm = P_rx_dBw + 30 = Power (in **dBm**) received at the Spectrum Analyzer

Then the expected power of the 1090 MHz signal received at the Spectrum Analyzer is given by the following equation.

EQUATION 1:

P_rx_dBw = 10*log(P_out) - Loss_TX + G_tx + Path_Loss + G_rx - Loss_RX

= 10*log(P_out) - Loss_TX + G_tx -33.1903022 -20*log(R) + G_rx - Loss_RX

Specifying a Range of 3 meters (i.e., the distance between the antennas along the reference line shown in Figure 3-1) to be used as the Range in the following procedure provides the following Equation 2.

P_rx_dBw = 10*log(P_out) - Loss_TX + G_tx - 33.1903022 - 9.54242509 + G_rx - Loss_RX

EQUATION 2:

P_rx_dBw = 10*log(P_out) - Loss_TX + G_tx - 42.73272729 + G_rx - Loss_RX

Note: *If the measurement distance, R, is different from 3 meters, then Equation 2 must be recomputed for the new R and the recomputation must be based on Equation 1. Equation 1 is based on the fact that there are 1852 meters in one nautical mile. Also, there are 6076.1 feet in one nautical mile. Therefore, for the purpose of these computations, there are 3.280831533 feet per meter.*

The Effective Radiated Power (ERP) emitted from the Transmitting Antenna is then given by Equation 3 as follows:

EQUATION 3:

ERP_dBw = P_rx_dBw + 42.73272729 - G_rx + Loss_RX

Note: *Whenever the need to measure radiated RF power is established, the question arises in regards to the permissible level of radiation that can be sustained by personnel making the measurements. This document addresses such concerns in the following paragraph of this note.*

Assume that the maximum Effective Radiated Power from the Transponder or ADS-B Transmitting Subsystem is 500 W (27 dBW) as specified in §2.2.2.1.2 of this document and §2.2.3.2.d of RTCA DO-181D. Then, using portions of equation 2 or 3 from above, the radiated power at 3 meters is given as follows:

P_3m_dBW = ERP - 42.73272729

= 26.98970004 dBW -42.73272729

P_3m_dBW = -15.74302725 dBW

then the power at 3 meters in watts is as follows:

$10*log(P\_3m\_W) = -15.74302725$

$P\_3m\_W = (10^{-1.574302725}$

$= 0.02665\ W$

$= 26.65\ mW$

This would appear to be a minimum amount of power: however, it does not readily translate into Maximum Permissible Exposure ***(MPE)*** *limits, which are typically used to determine hazard levels.*

Consulting FCC OET Bulletin 65, Edition 97-01, August, 1997, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," provides information as provided in the following paragraphs.

Section 2, equation 3, page 19 of the bulletin provides the following equation for the prediction of RF fields:

$$S = \frac{EIRP}{4\pi R^2}$$

where:

S = power density (in appropriate units, e.g. mW/cm^2)
EIRP = equivalent (or effective) isotropically radiated power (inappropriate units, e.g .mW)
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

Applying this equation at 3 meters to the maximum radiated power (e.g., 500 W) allowed for transponders or ADS-B Transmitting Subsystems provides the following results:

$$S = \frac{(500\ W)(1000\ mW/W)}{4\pi(300\ cm)^2}$$

$$= 0.44209706\ mW/cm^2$$

Appendix A, Table 1(A) of the bulleting then provides MPE limits for Occupational/Controlled Exposure as follows:

Frequency Range (MHz)	=	*300 - 1500*
Electric Field Strength (E) (V/m)	=	*Not Applicable*
Magnetic Field Strength (H) (A/M)	=	*Not Applicable*
Power Density (S) (mW/cm^2)	=	*f/300*
Averaging Time, S ***(minutes)***	=	*6*

Therefore, the MPE exposure for an average of 6 minutes at 1090 MHz is:

$S\_MPE\_1090 = (1090)/300 = 3.63333333...\ mW/cm^2$

Note that this limit value is 8.2184 times greater than the power density at 3 meters computed above as 0.44209706 mW/cm^2.

Next, the time of exposure must be considered. Page 11 of the bulletin addresses this concern with the equation:

$$\Sigma S_{exp} t_{exp} = S_{limit} t_{avg}$$

where:

S_{exp} = *power density of exposure* (mW/cm^2)

S_{limit} = *appropriate power density MPE limit* (mW/cm^2)

t_{exp} = *allowable time of exposure for* S_{exp}

t_{avg} = *appropriate MPE averaging time*

Taking into the consideration that the transponder or ADS-B Transmitting Subsystem will never exceed a transmitting duty cycle of 5%, the allowable time of exposure is computed from the above equation as follows:

$$(0.44209706\ mW/cm^2) * X * (0.05) = (1090/300\ mw/cm^2)(6\ minutes)$$

$$X = \frac{(1090/300\ mw/cm^2)(6\ minutes)}{(0.44209706\ mW/cm^2)(0.05)}$$

$$X = 986.209\ minutes$$

or

$$X = \mathbf{16.4368\ hours}$$

These calculations have demonstrated that the expected power density of the transponder or ADS-B Transmitting Subsystem at 3 meters is well within the allowable MPE. The calculations also demonstrate that the time of 16.44 hours of exposure to present a possible hazard is considerably longer than any time necessary to perform the test procedures address in this subparagraph.

Step 2: Measure the Output Power of the ADS-B Transmitting Subsystem or device

On the Aircraft (or other applicable installation), disconnect the ADS-B Transmitting Subsystem to Antenna connection at the ADS-B Transmitting Subsystem unit connector.

Using appropriate attenuators, connectors, and coaxial cable of known attenuation of 3 dB and impedance of 50 ohms, connect the Spectrum Analyzer to the ADS-B Transmitting Subsystem.

Note: *The use of attenuators is strongly recommended such that the RF receiver front end of the Spectrum Analyzer is not destroyed. If such happens, it is probable that the individual performing the test will not be performing similar tests in the future.*

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Surface Position Messages.

Using the Spectrum Analyzer set at a center frequency of 1090 MHz, capture the strongest (i.e., highest RF power) pulse in an ADS-B Surface Position Message Pulse Train. Then measure the frequency and pulse power.

Verify that the frequency is at 1090 MHz ±1.0 MHz.

For Class A0 equipment, verify that the output power is at least 70 watts (i.e., 18.45 dBw, or 48.45 dBm). Log the measurement as P_out.

For Class A1S, A1, A2, and A3 equipment, verify that the output power is at least 125 watts (i.e., 20.97 dBw, or 50.97 dBm). Log the measurement as P_out.

Step 3: Re-connect Aircraft Installation

Disconnect the Spectrum Analyzer from the ADS-B Transmitting Subsystem.

Restore the normal aircraft (or other) installation connection of the ADS-B transmitting antenna to the ADS-B Transmitting Subsystem.

Step 4: Establish Measurement Reference #1

Refer to Figure 3-1.

Using an appropriate strong nylon string or similar, secure the string to the Calibrated Sensing Antenna and to the Aircraft Antenna under test such that the two antenna are exactly 3 meters apart along the reference line shown in Figure 3-1. Make sure that the two antennas are at the same height from a relatively level surface. Note this position of the Calibrated Sensing Antenna as the **baseline** position.

Then, move the Calibrated Sensing Antenna to a point that is 5 degrees above the baseline position while maintaining the Calibrated Sensing Antenna perpendicular to the string with the string being tight but not stretched. Note this position as the **#1 Reference** Position.

Configure the ADS-B Transmitting Subsystem to transmit ADS-B Surface Position Messages.

Using the Spectrum Analyzer set at a center frequency of 1090 MHz, capture the strongest (i.e., highest RF power) pulse in an ADS-B Surface Position Message Pulse Train. Then measure and note the pulse power.

For Class A0 equipment, verify that the ERP (see Equation 3) is at least 70 watts (i.e., 18.45 dBw, or 48.45 dBm). Log the measurement as ERP_dBw.

For Class A1S, A1, A2, and A3 equipment, verify that the ERP (see Equation 3) is at least 125 watts (i.e., 20.97 dBw, or 50.97 dBm). Log the measurement as ERP_dBw.

Step 5: Circular Measurements

Keeping the Calibrated Sensing Antenna at 5 degrees above the baseline position as specified in Step 4, move the Calibrated Sensing Antenna in the horizontal plane in approximately 45 degree steps such that new positions are established at approximately 45, 90, 135, 180, 225, 270, and 315 degrees relative to **#1 Reference** Position.

At each new position, repeat the power measurement taken in Step 4 and log the results in dBw.

Verify that the maximum deviation between any two measurements taken in Step 4 and this Step does not exceed 1 dBw.

Step 6: Establish new reference #2

Repeat Step 4 with the Calibrated Sensing Antenna moved to a position that is 15 degrees above the **baseline** position. Note this position as the **#2 Reference** Position.

Repeat the power measurement made in Step 4.

Verify that the maximum difference between the measurement and that taken in Step 4 does not exceed 1 dBw.

Repeat Step 5 about the **#2 Reference** Position while maintaining the Calibrated Sensing Antenna at 15 degrees above the baseline position.

Verify that the maximum deviation between any two measurements taken in this Step does not exceed 1 dBw.

Step 7: Establish new reference #3

Repeat Step 4 with the Calibrated Sensing Antenna moved to a position that is 30 degrees above the baseline position. Note this position as the **#3 Reference** Position.

Repeat the power measurement made in Step 4.

Verify that the maximum difference between the measurement and that taken in Step 4 does not exceed 1 dBw.

Repeat Step 5 about the **#3 Reference Position** while maintaining the Calibrated Sensing Antenna at 30 degrees above the baseline position.

Verify that the maximum deviation between any two measurements taken in this Step does not exceed 1 dBw.

Step 8: Establish new reference #4

Repeat Step 4 with the Calibrated Sensing Antenna moved to a position that is 5 degrees below the baseline position. Note this position as the **#4 Reference** Position.

Repeat the power measurement made in Step 4.

Verify that the maximum difference between the measurement and that taken in Step 4 does not exceed 1 dBw.

Repeat Step 5 about the #4 Reference Position while maintaining the Calibrated Sensing Antenna at 5 degrees below the baseline position.

Verify that the maximum deviation between any two measurements taken in this Step does not exceed 1 dBw.

Step 9: Establish new reference #5

Repeat Step 4 with the Calibrated Sensing Antenna moved to a position that is 15 degrees below the baseline position. Note this position as the **#5 Reference** Position.

Repeat the power measurement made in Step 4.

Verify that the maximum difference between the measurement and that taken in Step 4 does not exceed 1 dBw.

Repeat Step 5 about the **#5 Reference** Position while maintaining the Calibrated Sensing Antenna at 15 degrees below the baseline position.

Verify that the maximum deviation between any two measurements taken in this Step does not exceed 1 dBw.

Step 10: Establish new reference #6

Repeat Step 4 with the Calibrated Sensing Antenna moved to a position that is 30 degrees below the baseline position. Note this position as the **#6 Reference** Position.

Repeat the power measurement made in Step 4.

Verify that the maximum difference between the measurement and that taken in Step 4 does not exceed 1 dBw.

Repeat Step 5 about the **#6 Reference** Position while maintaining the Calibrated Sensing Antenna at 30 degrees below the baseline position.

Verify that the maximum deviation between any two measurements taken in this Step does not exceed 1 dBw.

3.3.4.6.2 Verification of Receiver Pattern Gain (§2.2.13.2)

Purpose/Introduction:

The purpose of this procedure is to verify that the gain of an omni-directional antenna should not be less than the gain of a matched quarter-wave stub minus one dB over 90% of a coverage volume from 0 to 360 degrees in azimuth and -15 to +20 degrees in elevation when installed at the center of a 1.2 m (4 ft.) diameter (or larger) circular ground plane that can be either flat or cylindrical.

This procedure **shall** be performed on final installed equipment with all appropriate connections and antenna in order to demonstrate proper operation of the final installation.

Equipment Required:

Provide the same equipment capability as that provided in §3.3.4.6.1.

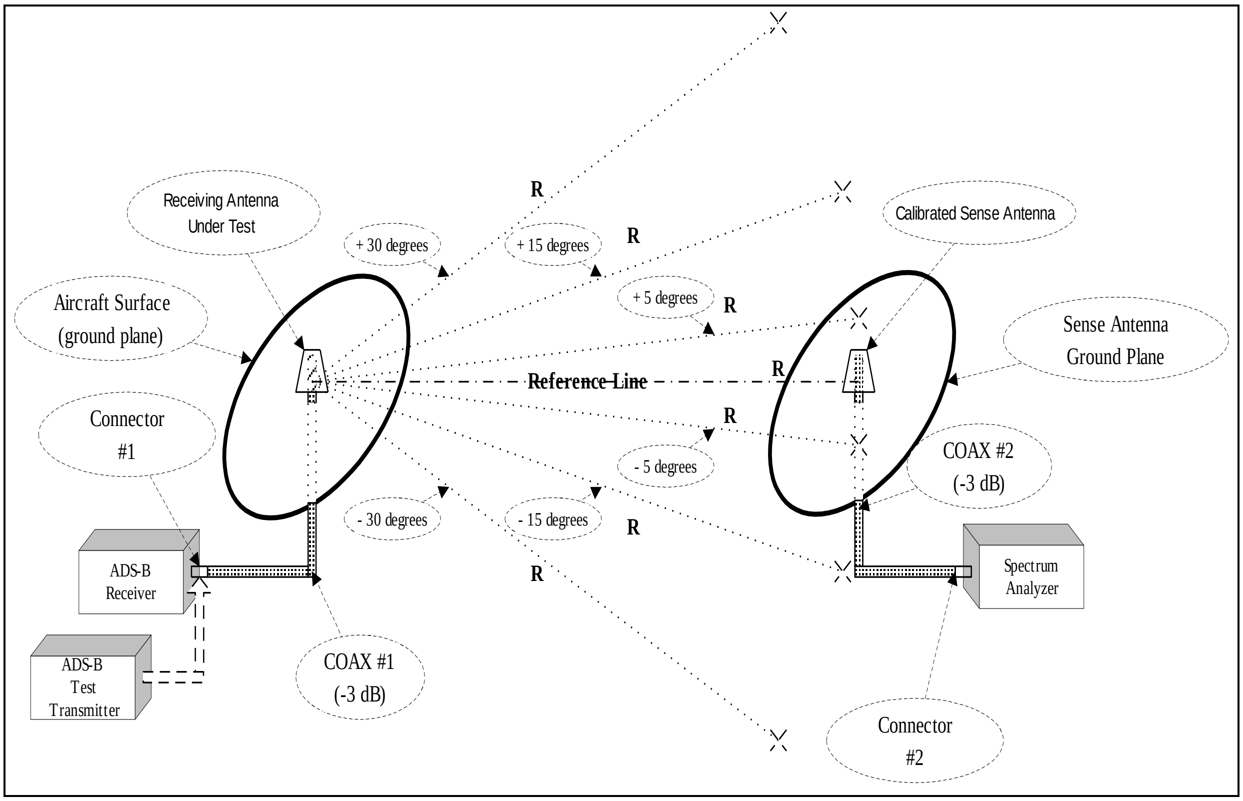


Figure 3-2: Antenna Test Configuration - 2

Measurement Procedure:

Note: *Figure 3-2, above, is exactly the same as Figure 3-1 provided in §3.3.4.6.1 with the exception that:*

a. The ADS-B Transmitter in Figure 3-1 has been replaced with an ADS-B Receiver and an ADS-B Test Transmitter that is to be patched in for this test procedure.

b. The Transmitting Antenna under Test in Figure 3-1 has been replaced with a Receiving Antenna under Test.

Step 1: Install ADS-B Transmission Capability

On the Aircraft (or other applicable installation), disconnect the ADS-B Receiving Device to Antenna connection at the ADS-B Receiving device unit connector.

For Class A0 Receiver installations, install an ADS-B Test Transmitting device having a minimum RF power of least 70 watts (i.e., 18.45 dBw, or 48.45 dBm) ***plus*** 3 dB. If additional cabling or connectors are required to make the connection, then the added attenuation must be accounted for when applying the equations given in §3.3.4.6.1 in this procedure.

For Class A1S, A1, A2, and A3 Receiver installations, install a ADS-B Test Transmitting device having a minimum RF power of least 125 watts (i.e., 20.97dBw, or 50.97 dBm) ***plus*** 3 dB. If additional cabling or connectors are required to make the connection, then the added attenuation must be accounted for when applying the equations given in §3.3.4.6.1 in this procedure.

At this point, the ADS-B Receiving device of the ADS-B Receiving installation has been replaced with an appropriate RF source such that the radiated pattern of the receiving antenna installation can be verified. The premise here is that if the radiated pattern is good, then so is the reception pattern.

Step 2: Perform Radiated Pattern Tests

Using the equations given in §3.3.4.6.1, with appropriate modifications if necessary, repeat steps 2 through 10 of §3.3.4.6.1.

Step 3: Restore Original Installation

Disconnect and remove the ADS-B Test Transmitter and restore the original installation of the ADS-B Receiving device.

3.3.4.6.3 Verification of Frequency Requirements for Transmit and Receive Antenna(s) (§2.2.13.3)

Procedures to properly verify the frequency of ADS-B Transmitting installations are provided in §3.3.4.6.1, step 2.

Procedures to properly verify the frequency of ADS-B Receiving installations are provided in §3.3.4.6.2 by verification of the transmission frequency capability.

3.3.4.6.4 Verification of Impedance and VSWR (§2.2.13.4)

Purpose/Introduction:

The purpose of this procedure is to verify that the VSWR produced by the antenna when terminated in a 50 ohm transmission line does not exceed 1.5:1 at 1090 MHz.

Equipment Required:

Appropriate Couplers and Connectors as required. Coaxial Connection of known attenuation (shown in Figure 3-1 and Figure 3-2 as Coax #2). Appropriate Attenuators as required. HP 8562E Network Analyzer (or equivalent capability)

Measurement Procedure:

Step 1: Install Network Analyzer

For ADS-B transmitting installations, disconnect the ADS-B Transmitting Subsystem to Antenna connection at the ADS-B Transmitting Subsystem unit connector.

For ADS-B receiving installations, disconnect the ADS-B Receiving device to Antenna connection at the ADS-B Receiving device unit connector.

Using appropriate attenuators, connectors, and coaxial cable of known attenuation and impedance, connect the Network Analyzer to the cable end of the Antenna connection (i.e., the connector just removed from the ADS-B Transmitting or Receiving device).

Note: *The use of attenuators is strongly recommended such that the RF front end of the Network Analyzer is not destroyed. If such happens, it is probable that the individual performing the test will not be performing similar tests in the future.*

Step 2: Perform Impedance and VSWR Measurements

Using the Network Analyzer, measure the impedance of the antenna installation at a frequency of 1090 MHz.

Verify that the impedance does not exceed 50 ohms.

Using the Network Analyzer, measure the Voltage Standing Wave Ratio (VSWR) of the antenna installation at a frequency of 1090 MHz.

Verify that the VSWR does not exceed 1.5:1.

3.3.4.6.5 Verification of Polarization (§2.2.13.5)

Procedures to properly verify that the ADS-B Transmitting antenna is vertically polarized are provided in §3.3.4.6.1.

Procedures to properly verify that the ADS-B Receiving antenna is vertically polarized are provided in §3.3.4.6.2.

3.4 Flight Environment Data Sources

Aircraft systems and/or sensors, which supply flight environment data to the ADS-B system, **shall** be selected to meet the accuracy, range, and resolution requirements appropriate to the equipage category. (Accuracy, range, and resolution may be shown to be adequate by analysis.)

3.4.1 Navigation Accuracy Category (NAC)

The system **shall** report (and adjust, if necessary) NAC values appropriate to the navigation source (including its operational mode) that supplies data to the ADS-B system. NAC value varies with navigation source selection and the selected sensor's current performance. If the aircraft has multiple navigation systems, NAC can vary with system selection and the mode of operation (e.g. Inertial Navigation with DME or GPS augmentation). The reported NAC value must vary to track navigation accuracy (NAC) as it increases or decreases, corresponding to navigation system accuracy.

3.4.2 Altitude

Barometric Pressure Altitude relative to a standard pressure of 1013.25 millibars (29.92 in.Hg.) **shall** be supplied to the ADS-B system . Altitude data, which is correctable for local barometric pressure, **shall** not be supplied to the ADS-B system. The ADS-B system and the ATC transponder (if installed) **shall** derive Pressure Altitude from the same sensor (e.g. air data computer or encoding altimeter).

3.4.3 Surface/ Air (Vertical) Status

Aircraft systems or sensors providing vertical status to the ADS-B system **shall** be implemented such that they provide a reliable indication that the aircraft is on the ground or airborne. When considering likely failure modes, the system should fail to the "air" mode where possible (e.g. air/ground relay should relax to the "air" mode).

3.5 Aircraft / Vehicle Data

ADS-B Messages contain information describing the aircraft or vehicle that is transmitting. It is a responsibility of the installer to insure that the vehicle information provided to the ADS-B system is correct.

3.5.1 Fixed Data

Data that does not change during operation, is selected or loaded at installation (e.g. ADS-B Emitter Category, ICAO address). Fixed data **shall** accurately represent the individual airplane/vehicle characteristics or registration information. If ADS-B and a Mode-S transponder are installed, both **shall** use the same ICAO address (whenever both are operating).

3.5.2 Variable Data

Controls used by the pilot/crew for data entry (e.g. flight number, call sign, emergency status) **shall** correctly perform their intended functions.

Note: *Where regulations permit variation of the 24 bit Mode-S and /or ADS-B address, ADS-B and a Mode-S transponder **shall** use the same ICAO address (whenever both are operating).*

3.5.3 On-condition Sensors

Aircraft systems or sensors used to trigger on-condition messages **shall** be selected and implemented such that they provide a reliable indication of the specific condition(s) to be reported.

3.5.4 Class Code (basic)

Class code information **shall** be set to accurately transmit the capability of the system as it is installed. Class code can vary between aircraft depending upon installed options and equipment variations

3.5.5 Capability Class Data

Capability class data include en route, terminal area, approach and landing, and surface operations capability information supplied by installed applications. Capability class data must respond to changes in the availability of operational mode data (§2.2.5.1.21 - §2.2.5.1.27).

3.6 Flight Test Procedures

This guidance material offers examples of flight test procedures for demonstration of performance of selected functions.

Flight testing of installed systems may be desirable to confirm or supplement bench and ground tests of installed performance.

Flight tests are not necessary to evaluate functions that encode, communicate, and decode messages, assemble reports, or generate displays, except for the radio frequency functions associated with transmission and reception of ADS-B Messages.

3.6.1 Displayed Data Readability

Determine that normal conditions of flight do not significantly affect the readability of displayed data.

3.6.2 Interference Effects

For those aircraft systems and equipment that can only be tested in flight, determine that no operationally significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operational modes.

Note: *Electromagnetic interference flight tests are often conducted on all electronic systems in one test series, using procedures established by the aircraft manufacturer. If such tests included the ADS-B equipment, no further tests are required. (e.g. ADS-B functionality added to an existing transponder and/or TCAS installation)*

3.6.3 Surveillance Testing

The surveillance flight test is designed to verify that the installed ADS-B system is capable of transmitting and/or receiving ADS-B squitter messages from other aircraft. The following suggested procedures are typical flight test plans that could be followed in a region of low air traffic density: but any other test that supplies equivalent data would be acceptable.

ADS-B system testing requires verification of transmission and reception of ADS-B Messages at the minimum range for the equipage class. If testing an aircraft installation ("Subject") that broadcasts only, the receiving equipment ("Target") must provide a means to display message information, received from the Subject, to the operator.

Shorter range (10 - 20 NM) operational requirements may be demonstrated using a ground based Target system. Longer range operation might require an airborne Target system. Typically the airborne Target aircraft will fly a holding pattern at a designated fix and within 3000 feet of the Subject aircraft altitude.

Fly the Subject aircraft straight and level at the minimum operational range and verify that data from the Subject are received reliably by the Target system. If the Subject system has receive capability, verify that the Subject system reliably reports information about the Target. (e.g. displays Target at appropriate range and altitude with correct identification)

Note: *It is not intended that reception of individual squitter messages be verified.*

Fly the Subject aircraft in a figure 8 pattern, at the minimum operational range, at bank angles consistent with normal operations, at a constant altitude, and verify that transmitted data are received reliably by the Target system. If the Subject system has receive capability, verify that the Subject system reliably reports information about the Target during maneuvering. (e.g. displays Target at appropriate range and altitude with correct identification)

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4.0 Operational Characteristics and Functional Requirements

A description of 1090 MHz ADS-B System operation is followed by functional requirements for the System.

4.1 System Operation

This subsection describes the operation of a generic/hypothetical ADS-B system during typical phases of flight operations. The phases considered are: pre-flight, taxi out, take off/departure, en route, approach, landing/taxi, and shutdown. A transport aircraft is assumed, possessing a full complement of sensors to allow reliable detection of various phases of flight. Less complicated systems or aircraft might incorporate fewer modes of operation and variations on mode selection logic.

4.1.1 General Operation: Transmitting Subsystem

The system has multiple operating modes to vary the amount and type of data transmitted as appropriate to the operating environment and to minimize traffic on the radio frequency data link(s). Mode selection should be automated to the greatest practical degree to reduce crew work load and enhance system utility.

Pre-flight: Electrical power is applied to the airplane, thus powering the ADS-B system components. The ADS-B function performs internal power up self tests, selects the transmitter to Standby mode, if available, and begins to collect data about own ship for transmission.

Firm data such as tail number or 24-bit ICAO address is loaded or reloaded. Flight number, if used, is set to all zeros as a result of the power having been removed for a time in excess of the transient switching interval protection. The system, sensing that the aircraft is on the ground, attempts to acquire a new flight number (flight number sometimes will change whenever the aircraft is on the ground). System power might not be interrupted. Position (latitude/longitude/altitude) is acquired and State Vector messages are prepared and refreshed as required to maintain current information ready for transmission.

Taxi Out: When the crew selects "on" or the ADS-B function detects a taxi, or imminent operational condition (e.g. an engine oil pressure discrete + brake release + doors closed while on the ground) the Surface mode is selected and squitter transmission commences, transmitting State Vector and Partial Mode Status messages (flight identification). Squitters might be transmitted at a reduced rate while on the ground. (General aviation airplanes might sense a GPS ground speed /position exceeding an accuracy threshold.)

Note: *Regulations might preclude automatic squitter commencement during taxi, limiting transmissions to the movement area. Crew action may be required to begin squitter transmissions. Transmitter power should not be reduced during surface operations, in order to maintain probability of reception in competition with proximate airborne transmitters.*

Take off / Departure: When the ADS-B function detects a take off (e.g., speed (IAS or Ground Speed) in excess of an appropriate minimum) the Air mode is selected. Transmitted message type and squitter rate are adjusted as appropriate. The on-ground status is broadcast until the ADS-B function detects an airborne condition (e.g. landing gear WOW/squat switch) or associated conditions are met to override a malfunctioning squat switch.

En route: Continue transmitting in Air mode.

Approach: Continue transmitting in Air mode. When the aircraft transitions to approach (e.g. flaps set appropriately for landing and speed reduced accordingly), the Air mode is continued and appropriate messages to support on-condition reports may be sent.

Landing / Taxi in: When the ADS-B function detects a landing configuration (e.g. gear down (general aviation airplanes could use flap position only, or allow pilot selection), the Air mode is continued and appropriate messages to support on-condition reports may be sent. Surface mode is not entered until the ADS-B function detects an on-ground condition (e.g. landing gear Weight On Wheels/squat switch). (General aviation airplanes might use an appropriate IAS or Ground Speed, corresponding to minimum stall speed, dirty.) Logic should be biased toward the air mode in case of a squat switch failure.

Shutdown: When the crew selects “Stand-by” squitter ceases.

Note: *Regulations might limit squitter during taxi, to the movement area. Crew action may be required to inhibit transmission of squitters.*

4.1.2 General Operation: Receiving Subsystem

The ADS-B system receive function performs two tasks. A radio frequency receiver detects squitters from external sources and decodes messages. A report generator collects and organizes the individual messages into reports and outputs the reports on a data bus(s) to user applications. The most likely application is a cockpit display of traffic information (CDTI). Other applications might include a conflict detector to inform the pilot if separation from other traffic is predicted to be less than desired. A logical extension of the conflict detector is advisory information for maintaining the desired separation distance.

This section describes the operation of a generic/hypothetical ADS-B system receiver. Unlike the ADS-B transmitter, the receiver operation varies only slightly with the phase of flight. The RF squitter receiver continues to detect and decode any and all recognizable ADS-B Messages. The report generator accepts control inputs from applications which allow it to filter out messages which are not of importance to the application. Filtering allows for more efficient use of the available computing resources.

Pre-flight: Electrical power is applied to the airplane, thus powering the ADS-B system components. The ADS-B function performs internal power up self tests. The ADS-B receiver monitors the 1090 MHz frequency for squitters from other aircraft and generates reports for user systems such as a Cockpit Display of Traffic Information (CDTI). Receiver sensitivity may be reduced in the Surface mode. The report generator collects data about own ship such as tail number or ICAO address, used to recognize its own squitter transmissions. Position (latitude/longitude/altitude) is acquired and continuously updated for message filtering based on range or altitude and for conflict detection. The report generator may accept filter criteria from ADS-B applications and send to each application only the appropriate traffic reports.

Taxi Out: The receiver decodes messages and supplies them to the report generator. The report generator, having received filter information from the CDTI, sends it reports only on traffic, which is within the CDTI-selected range and altitude. The report generator, also having received filter information from a concurrently executing conflict detection application, sends it messages only from traffic whose position and altitude is consistent with aircraft or vehicles in the airport traffic pattern or movement area. (Report filter criteria may differ between applications.)

Take off / Departure: (same as preflight and taxi out except receiver sensitivity is at maximum in the Air mode.)

En route: The receiver decodes messages and supplies them to the report generator. The report generator, having received a range selection from the CDTI, sends it reports only on traffic which is within the CDTI-selected range and altitude. The report generator, having received different filter information from another concurrently executing application, might send that further application reports on all traffic with an altitude greater than some threshold, (possibly selected to reject traffic in overflown airport patterns or on the surface) or near own altitude and within a given range.

Approach: The receiver decodes messages and supplies them to the report generator. The report generator, having received a range selection from the CDTI, sends it reports only on traffic which is within the CDTI-selected range and altitude. The report generator, having received approach filter information from another concurrently executing ADS-B application, might send that further application only reports consistent with aircraft in the airport traffic pattern.

Landing / Taxi in: The receiver decodes messages and supplies them to the report generator. The report generator, having received a range selection from the CDTI, sends its reports on traffic that is within the CDTI-selected range and altitude. Having received landing filter information from another concurrently executing ADS-B application that detected Gear down (i.e. "Landing"), the generator includes reports on traffic that is on the surface. On touch down, the application filter criteria might be revised to reject airborne traffic above the local pattern altitude.

Shutdown: The receiver decodes messages and supplies them to the report generator until power is removed or a standby mode is selected.

4.2 Operating Modes

4.2.1 Operating Modes: Transmit

The 1090 MHz ADS-B system has two modes of operation, surface and air. Operational modes control variable link characteristics such as message types to be transmitted and squitter rates. Switching between modes is accomplished automatically as required in §2.2.3.2.1.2. Operational mode selection may be determined by reference to State Vector (SV) data elements such as speed. It is possible to force the system to either mode while the aircraft is on the ground for testing (§2.2.11.1).

4.2.1.1 Surface Mode

Surface mode is used on the ground but might be extended to low altitudes during take-off or approach. In the Surface mode of operation, the system transmits State Vector messages and Mode Status (Flight Identification) at a reduced squitter rate and possibly with reduced receiver sensitivity levels. When the 1090 MHz ADS-B System is implemented using a transponder, it is possible for a Mode-S ground sensor to command an airborne system to operate in the surface mode for brief periods of time (see RTCA DO-181D; §2.2.23.1.5.2).

4.2.1.2 Air Mode

In the Air mode of operation, the system transmits all message types appropriate to its equipment class at the designated rates and power output level.

4.2.2 Automatic Operation

The system transmits the required squitters for the equipment class, without crew intervention. Own aircraft ADS-B position and velocity messages are formatted and transmitted without crew member inputs or adjustments such as mode selection or tuning. Similarly, ADS-B Messages from other sources are received, formatted into reports, and output to user systems, or displays, without crew member intervention. (Mode selection on CDTI or other displays is acceptable since they are not considered part of the ADS-B function.)

An exception is the Participant Address (ICAO 24-bit address). In most installations, the address does not change and is "hard wired" at installation. Where permitted by regulatory authorities, this address may be input by the crew.

Certain messages related to Mode Status and On-Condition reports may be triggered by crew actions that satisfy the conditions for the automatic generation of an associated message.

ADS-B System validity status is available to the crew, as required in §2.2.11.5.

Crew member input of Mode Status (MS) information, where practical, (e.g., flight number) is acceptable. The capability to acquire all message elements automatically is desirable. Automatic acquisition of data reduces crew work load and avoids data entry errors. Supplemental information may be entered via associated equipment.

4.3 Self Test

4.3.1 Receive

If the system performs self tests, testing should indicate the ability to receive ADS-B messages.

If the system generates test squitter transmissions to verify the ADS-B receiver function, the self test signal level at the antenna end of the transmission line **shall** not exceed –40 dBm as required in §2.2.11.1.

4.3.2 Transmit

If the system performs self tests, testing should indicate the ability to send ADS-B Messages. That ability implies the availability of the required message elements, whether derived internal to the system or provided by other aircraft systems. The ability to send messages also implies the availability of the 1090 MHz data link transmitter.

Note: *The presence of valid incoming message(s) (from other than own ship) is not required to indicate the availability of a data link. The ADS-B system may rely on the link system flags, valids, self test etc. to determine availability. (ADS-B self test failure, attributed to a data link failure, should nominate the data link in a BIT message.)*

4.3.2.1 Broadcast Monitor

If the 1090 MHz ADS-B System is not implemented using a transponder, a squitter monitor verifies that the ADS-B transmitter generates squitter transmissions at a nominal rate. The transmitter is considered to have failed when the monitor has detected squitter failure. (ref. §2.2.11.2)

4.3.2.2 Address Monitor

If the 1090 MHz ADS-B System is not implemented using a transponder, a Participant Address monitor is provided. In the event that the ADS-B-transmitted Participant Address is all zeros or all ones, the system declares a failure. (§2.2.11.3)

4.3.2.3 Failure Annunciation

An output is provided to indicate the validity/non-validity of the ADS-B system. Failure to generate squitters at the nominal rate, a failure detected by self-test, or a failure of the ICAO address verification causes the output to assume the invalid state. Momentary power interrupts should not cause the output to latch in the invalid state. The detection of a failure is annunciated to the flight crew. (§2.2.11.5)

4.4 Controls

4.4.1 Power On/Off (Optional)

The system should be powered whenever primary electrical power is available. Circuits powering various system components or functions may be protected by individual circuit breakers. Components or functions may receive power from multiple sources or busses (e.g. 115 vac and 28vdc).

Aircraft with limited electrical system capacity may employ system power controls for energy conservation.

4.4.2 Manual Test (Optional)

The system should provide a means for a manually initiated test of the system report generation function(s).

4.4.2.1 Traffic Report

The manual test should cause the system to output a report of a "Test" traffic target such that the "Test" target appears on an associated CDTI display at a specified bearing and distance from the own-aircraft symbol.

4.4.2.2 State Vector Report

The test should include a means for the crew or maintenance personnel to verify a subset of parameters in the own-aircraft SV report data. The verifiable parameters should include: Position (Latitude, Longitude), Pressure Altitude, and Speed. (e.g. The "Test" target displays own aircraft altitude, heading (or ground track) and speed (IAS or Ground Speed) while applying a constant offset to own aircraft latitude and/or longitude.)

4.4.3 Participant Address (Optional)

At the manufacturer's option, a means may be provided to alter the unique participant address of the aircraft, within an allocated block of ICAO 24-bit addresses.

Note: *The system architecture will determine if the ICAO 24-bit address is entered into the data link unit or an associated peripheral device.*

4.4.4 Flight Number (Optional)

At the manufacturer's option, a means may be provided for the flight crew to enter the flight identification number or registration ("N" number, or equivalent).

Note: *The system architecture will determine if flight identification or registration number is entered into the data link unit or an associated peripheral device.*

4.4.5 1090 MHz ADS-B Link Control (Optional)

At the manufacturer's option, a means may be provided for the flight crew to disable the 1090 MHz ADS-B link. Disabling results in the cessation of transmission and/or reception of ADS-B Messages on 1090 MHz. Control of transmission and reception of any other installed ADS-B systems is independent of the 1090 MHz ADS-B system status.

4.4.6 Standby

A means **shall** be provided for the flight crew to select a standby mode in which squitter transmissions are inhibited.

4.4.7 Mode Control

The transmit function will accept appropriate data for on-condition or event driven message transmissions, as appropriate to the equipment capability classification. At the manufacturer’s option, a means may be provided for the flight crew to enter this data (e.g. Minimum Fuel, No Communications, Unlawful Interference, etc.)

Control of Surface and Air mode switching **shall** not be available to the flight crew.

4.4.8 Barometric Altitude

A means **shall** be provided for the flight crew to inhibit the broadcast of barometric altitude if directed to do so by ATC.

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Paul Gross	Arthur D. Little, Inc.
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Edward Hahn	The MITRE Corporation
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John Hallinan	Federal Aviation Administration
Barbara Harrelson	Trios Associates, Inc.
David Hartnett	Federal Aviation Administration
Edgar Heath	Department of Defense
Jim Herbert	SETA
Val Heinz	MIT Lincoln Laboratory
Douglas Helton	UPS Aviation Technologies
Bruce Henry	Federal Aviation Administration
Stephen Heppe	Telenergy
James Higbie	The Johns Hopkins University
Robert Hilb	United Parcel Service
Craig Hodgdon	Titan Systems Corporation
Eric Hoffman	Eurocontrol
Steven Horvath	UPS Aviation Technologies
Kris Hutchison	ARINC Incorporated
Peter Hwoschinsky	Federal Aviation Administration
Robert Jackson	Raytheon Systems Company
Messimore James	BAE Systems, Inc.
Michael Jenkins	The MITRE Corporation
James Johnson	Federal Aviation Administration
Stanley Jones	The MITRE Corporation
Ed Juleau	NTIA, Department of Commerce
Kathleen Kearns	SITA
Randy Kenagy	Aircraft Owners & Pilots Association
Robert Kerr	Honeywell International, Inc.
William Kight	Independent Pilots Association
Ludwig Kilchert	Generic Aircraft Systems
Deborah Kirkman	The MITRE Corporation
Worth Kirkman	The MITRE Corporation
James Klein	Rockwell Collins, Inc.
Steve Koczo	Rockwell Collins, Inc.
Yoshio Kubota	Japan Air Line Company
James Kukla	Lockheed Martin Corporation
Daryal Kuntman	Honeywell International, Inc.

Dieter Kuuze	Becker Flugfunkweik GmbH
Chuck LaBerge	Honeywell International, Inc.
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Antonio LoBrutto	Sensis Corporation
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Christopher Machin	Eurocontrol
Frank Mackowick	SkyComm, Inc.
Robert Magee	Mulkerin Associates, Inc.
Robert Manning	L-3 Communications Analytics Corp. - U.S. Air Force
Eby Martin	Source Code Systems, Inc.
Gerry McCartor	Federal Aviation Administration
Edwin McConkey	SAIC
James McDaniel	Federal Aviation Administration
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Appendix A

Extended Squitter and TIS-B

Formats and Coding Definitions

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A Extended Squitter and TIS-B Formats and Coding Definitions

A.1 ADS-B 1090 MHz Formats and Coding

A.1.1 Introduction

This Appendix is intended to be consistent with Section 2 of these MOPS. However, in the event of conflict between this Appendix and Section 2, the requirements in Section 2 **shall** take precedence.

Notes:

1. *This section of Appendix A defines the formats and coding for Extended Squitter ADS-B Messages. When Extended Squitter capability is incorporated into a Mode S transponder, the registers used to contain the Extended Squitter messages are part of the transponder's Ground-Initiated Comm-B service. This service consists of defined data available on board the aircraft being put into one of the 255 registers (each with a length of 56 bits) in the Mode S transponder by a serving process, e.g. ADS-B, at specified intervals. The Mode S ground interrogator can extract the information from any of these registers at any time and pass it to the ground-based application. In the case of Extended Squitter, the information in the registers defined for ADS-B are spontaneously broadcast as specified in RTCA/DO-181D. Extended Squitter messages are generated by the Mode S transponder at periodic rates as defined by RTCA/DO-181D, when data is present in Register numbers 05_{16}, 06_{16}, 08_{16}, and 09_{16}. Each time data is loaded into Register $0A_{16}$ the transponder will broadcast a single event-driven Extended Squitter. Data loaded into Registers 07_{16}, 61_{16}, 62_{16}, and 63_{16} while related to the Extended Squitter services is not used directly by the transponder for any Extended Squitter broadcast. However the contents of these registers is available as part of the transponder's Ground-Initiated Comm-B service.*

2. *If the Extended Squitter capability is implemented as a Non-Transponder Device, the convention for register numbering does not apply. However, the data content is the same as specified for the transponder case, and the transmit times are as specified in the body of these MOPS.*

A.1.2 Register Allocation Related to Extended Squitter

Table A-1: Register Allocation

Register number	Assignment	Maximum update interval
05_{16}	Extended Squitter Airborne Position	0.2 s
06_{16}	Extended Squitter Surface Position	0.2 s
07_{16}	Extended Squitter Status	1.0 s
08_{16}	Extended Squitter Identification and Category	15.0 s
09_{16}	Extended Squitter Airborne Velocity	1.3 s
$0A_{16}$	Extended Squitter Event-Driven Information	variable
10_{16}	Data Link Capability Report	≤4.0 s (see Note 2)
17_{16}	Common usage Capability Report	5.0 s
18_{16} – $1C_{16}$	Mode S Specific Services Capability Report	See Note 5
$1D_{16}$-$1F_{16}$	Mode S Specific Services Capability Report	5.0 s
20_{16}	Aircraft Identification	5.0 s
30_{16}	TCAS Active Resolution Advisory	Annex 10, Vol IV §4.3.8.4.2.2
61_{16}	Emergency/Priority Status	1.0 s
62_{16}	Target State and Status Information	0.5 s
63_{16}-64_{16}	Reserved for Extended Squitter	
65_{16}	Aircraft Operational Status	2.5 s
66_{16}-$6F_{16}$	Reserved for Extended Squitter	

Notes:

1. *The Register number is equivalent to the BDS B-Definition Subfield (BDS) value §2.2.14.4.20.b of DO-181D.*

2. *For ADS-B implementations on Mode S transponders, the data link capability report (Register 10_{16}) is used to indicate Extended Squitter capability (bit 34) and the contents of this Register are updated within one second of the data changing and at least every four seconds thereafter.*

3. *Register $0A_{16}$ is not to be used for GICB or ACAS crosslink readout.*

4. *The term "minimum update rate" is used in this document. The "minimum update rate" is obtained when data is loaded in one Register field once every "maximum update interval."*

5. *A bit set in one of these Registers indicates that the service loading the Register indicated by that bit has been installed on the aircraft. In this regard, these bits are not cleared to reflect a real time loss of an application, as is done for Register 17_{16}.*

The details of the data to be entered into the registers assigned for Extended Squitter will be as defined in this Appendix. Table A-1 specifies the minimum update rates at which the appropriate transponder register(s) will be reloaded with valid data. Any valid data will be reloaded into the relevant field as soon as it becomes available at the Mode S

Specific Services Entity (SSE) interface regardless of the update rate. If data are not available for a time no greater than twice the specified "maximum update interval," or 2 seconds (whichever is the greater), then the status bit (if provided) will indicate that the data in that field are invalid, and the field will be ZEROed.

A.1.3 General Conventions on Data Formats

A.1.3.1 Validity of Data

The bit patterns contained in the 56-bit transponder registers **shall** be considered to be valid application data only if:

1. The Mode S specific services capability is present. This is indicated by bit 25 of the data link capability report contained in BDS 1,0 being set to "ONE;"

2. The service corresponding to the application is shown as "supported" by the corresponding bit in the Common Usage Capability Report (BDS 1,7) being set to "ONE" for the Extended Squitter Registers 05_{16} to $0A_{16}$ inclusive.

   Notes:

   1. *The intent of the capability bits in Register 17_{16} is to indicate that useful data is contained in the corresponding register. For this reason, the bit for a register is cleared if data becomes unavailable (§A.1.6.2) and set again when data insertion into the register resumes.*

   2. *A bit set in Register 18_{16} to $1C_{16}$ indicates that the application using this register has been installed on the aircraft. These bits are not cleared to reflect a real time loss of an application, as is done for Register 17_{16}.*

3. The data value is valid at the time of extraction. This is indicated by a data field status bit (if provided). When this status bit is set to "ONE," the data field(s) which follow, up to the next status bit, are valid. When this status bit is set to "ZERO," the data field(s) are invalid.

A.1.3.2 Representation of Numerical Data

Numerical data **shall** be represented as follows:

1. Numerical data are represented as binary numerals. When the value is signed, 2's complement representation is used, and the bit following the status bit is the sign bit.

2. Unless otherwise specified, whenever more bits of resolution are available from the data source than in the data field into which that data is to be loaded, the data **shall** be rounded to the nearest value that can be encoded in that data field.

   Note: *Unless otherwise specified, it is accepted that the data source may have less bits of resolution than the data field.*

3. When the data source provides data with a higher or lower range than the data field, the data shall be truncated to the respective maximum or minimum value that can be encoded in the data field.

4. Where ARINC 429 data are used, the ARINC 429 status bits 30 and 31 are replaced with a single status bit, for which the value is VALID or INVALID as follows:

   a) If bits 30 and 31 represent "Failure Warning, No Computed Data" then the status bit **shall** be set to "INVALID."

   b) If bits 30 and 31 represent "Functional Test" then the status bit **shall** be set to "INVALID."

   c) If bits 30 and 31 represent "Normal Operation," "plus sign," or "minus sign," then the status bit **shall** be set to "VALID" provided that the data are being updated at the required rate.

   d) If the data are not being updated at the required rate, then the status bit **shall** be set to "INVALID."

   For interface formats other than ARINC 429, a similar approach is used.

5. In all cases where a status bit is used, it must be set to "ONE" to indicate VALID and to "ZERO" to indicate INVALID.

   Note: *This facilitates partial loading of the registers.*

6. When specified in the field, the switch bit **shall** indicate which of two alternative data types is being used to update the parameter in the transponder Register.

7. Where the sign bit (ARINC 429 bit 29) is not required for a parameter, it has been actively excluded.

8. Bit numbering in the MB field **shall** be as specified in Annex 10, Volume IV, §3.1.2.3.1.3.

9. Registers containing data intended for broadcast Comm-B **shall** have the broadcast identifier located in the eight most significant bits of the MB field.

Notes:

1. *When multiple data sources are available, the one with the highest resolution should be selected.*

2. *By default, values indicated in the range of the different fields of registers have been rounded to the nearest integer value or represented as a fraction.*

3. *As used in these MOPS, BDS A,B is equivalent to Register Number AB_{16}.*

A.1.4 Extended Squitter Formats

A.1.4.1 Format TYPE Codes

The first 5-bit ("ME" bits 1 – 5, Message bits 33 – 37) field in every Mode S Extended Squitter message will contain the format TYPE. The format TYPE will differentiate the messages into several classes: Airborne Position, Airborne Velocity, Surface Position, Identification, Aircraft Intent, Aircraft State, etc. In addition, the format TYPE will also encode the Navigation Integrity Category (NIC) of the source used for the position report. The format TYPE will also differentiate the Airborne Messages as to the TYPE of their altitude measurements: barometric pressure altitude or GNSS height (HAE). The 5-bit encoding for format TYPE will conform to the definition contained in Table A-2.

Table A-2: "TYPE" Subfield Code Definitions (DF = 17 or 18)

TYPE Code	Subtype Code	NIC Supplement A	NIC Supplement B	NIC Supplement C	Format (Message Type)	Horizontal Containment Radius Limit (R_C)	Navigation Integrity Category (NIC)	Altitude Type	Notes
0	Not Present	*Not Applicable*			No Position Information (**Airborne or Surface Position Messages**)	R_C unknown	NIC = 0	Baro Altitude <u>or</u> No Altitude Information	1, 2, 3
1	Not Present	*Not Applicable*			**Aircraft Identification and Category Message** (§2.2.3.2.5, §A.1.4.4)	*Not Applicable*	*Not Applicable*	*Not Applicable*	Category Set D
2									Category Set C
3									Category Set B
4									Category Set A
5	Not Present	0	--	0	**Surface Position Message** (§2.2.3.2.4, §A.1.4.3)	R_C < 7.5 m	NIC = 11	No Altitude Information	
6		0	--	0		R_C < 25 m	NIC = 10		
7		1	--	0		R_C < 75 m	NIC = 9		6
		0	--	0		R_C < 0.1 NM (185.2 m)	NIC = 8		
8		1	--	1		R_C < 0.2 NM (370.4 m)	NIC = 7		
		1	--	0		R_C < 0.3 NM (555.6 m)	NIC = 6		
		0	--	1		R_C < 0.6 NM (1111.2 m)	NIC = 6		
		0	--	0		R_C ≥ 0.6 NM (1111.2 m) or unknown	NIC = 0		
9	Not Present	0	0	--	**Airborne Position Message** (§2.2.3.2.3, §A.1.4.2)	R_C < 7.5 m	NIC = 11	Baro Altitude	5
10		0	0	--		R_C < 25 m	NIC = 10		5
11		1	1	--		R_C < 75 m	NIC = 9		5, 6
		0	0	--		R_C < 0.1 NM (185.2 m)	NIC = 8		
12		0	0	--		R_C < 0.2 NM (370.4 m)	NIC = 7		
13		0	1	--		R_C < 0.3 NM (555.6 m)	NIC = 6		
		0	0	--		R_C < 0.5 NM (925 m)	NIC = 6		
		1	1	--		R_C < 0.6 NM (1111.2 m)			
14		0	0	--		R_C < 1.0 NM (1852 m)	NIC = 5		
15		0	0	--		R_C < 2 NM (3.704 km)	NIC = 4		
16		1	1	--		R_C < 4 NM (7.408 km)	NIC = 3		7
		0	0	--		R_C < 8 NM (14.816 km)	NIC = 2		
17		0	0	--		R_C < 20 NM (37.04 km)	NIC = 1		
18		0	0	--		R_C ≥ 20 NM (37.04 km) or unknown	NIC = 0		
19	0	*Not Applicable*			Reserved	*Not Applicable*	*Not Applicable*	Difference between "Baro Altitude" and "GNSS Height (HAE)"	
	1 – 4				**Airborne Velocity Message** (§2.2.3.2.6, §A.1.4.5)				
	5 – 7				Reserved				
20	Not Present	0	0	--	**Airborne Position Message** (§2.2.3.2.3, §A.1.4.2)	R_C < 7.5 m	NIC = 11	GNSS Height (HAE)	2, 5
21		0	0	--		R_C < 25 m	NIC = 10		2, 5
22		0	0	--		R_C ≥ 25 m or unknown	NIC = 0		2

Table A-2: "TYPE" Subfield Code Definitions (DF = 17 or 18) (Continued)

TYPE Code	Subtype Code	NIC Supplement	Format (Message Type)
23	0	*Not Applicable*	**Test Message** (§2.2.3.2.7.3)
	1 – 6		Reserved
24	0		**Reserved**
	1		**Surface System Status** (§2.2.3.2.7.4) (Allocated for National Use)
	2 – 7		**Reserved**
25 – 26			**Reserved** (§2.2.3.2.7.5 and §2.2.3.2.7.6)
27			**Reserved for Trajectory Change Message** (§2.2.3.2.7.7)
28	0		**Reserved**
	1		**Extended Squitter Aircraft Status Message (Emergency/Priority Status)** (§A.1.4.8)
	2		**Extended Squitter Aircraft Status Message (TCAS RA Broadcast)** (§A.1.4.8)
	3 – 7		**Reserved**
29	0		**Target State and Status Message** (§A.1.4.9) (ADS-B Version Number=1, defined in RTCA DO-260A)
	1		**Target State and Status Message** (§A.1.4.9) (ADS-B Version Number=2, defined in these MOPS, RTCA DO-260B)
	2 - 3		Reserved
30	0 – 7		**Reserved**
31	0 – 1		**Aircraft Operational Status Message** (§A.1.4.10)
	2 – 7		Reserved

Notes for Table A-2:

1. *"Baro-Altitude" refers to barometric pressure altitude, relative to a standard pressure of 1013.25 millibars (29.92 in Hg). It does not refer to baro corrected altitude.*

2. *TYPE codes 20 to 22 or TYPE Code 0 are to be used when valid "Baro Altitude" is not available.*

3. *After initialization, when horizontal position information is not available but altitude information is available, the Airborne Position Message is transmitted with a type code of zero in bits 1-5, the barometric pressure altitude in bits 9 to 20, and bits 22 to 56 set to ZERO. If neither horizontal position nor barometric altitude information is available, then all 56 bits of Register 05_{16} are set to ZERO. The ZERO (binary 00000) TYPE Code field indicates that Latitude and Longitude information is not available, while the ZERO altitude field indicates that altitude information is not available.*

4. *If the position source is an ARINC 743A GNSS receiver, then the ARINC 429 data "label 130" data word from that receiver is a suitable source of information for R_C, the horizontal integrity containment radius. (The label 130 data word is variously called HPL (Horizontal Protection Limit) or HIL (Autonomous Horizontal Integrity Limit) in different documents.*

5. *This TYPE Code value implies limits for the R_C (horizontal containment limit). If this limit is not satisfied, then a different value for the TYPE Code should be selected.*

6. *The "NIC supplement" field in the Airborne Position Message (§A.1.4.2) and in the Aircraft Operational Status Message (§0) enables the Report Assembly Function in ADS-B Receiving Subsystems to determine whether the ADS-B Transmitting Subsystem is announcing NIC=8 (R_C < 0.1 NM) or NIC=9 (R_C < 75 m).*

7. *The "NIC supplement" field in the Airborne Position Message (§A.1.4.2) and in the Aircraft Operational Status Message (§0) enables the Report Assembly Function in ADS-B Receiving Subsystems to determine whether the ADS-B Transmitting Subsystem is announcing NIC=2 (R_C < 8 NM) or NIC=3 (R_C < 4 NM).*

8. *The term "broadcast" as used in this Appendix, refers to a spontaneous transmission by the transponder. This is distinct from the Comm-B broadcast protocol.*

9. *Future versions of these MOPS may limit transmission of Surface Position Messages at lower NIC and/or NAC_P values for Transponder-Based systems.*

A.1.4.1.1 Airborne Position Message TYPE Code

A.1.4.1.1.1 Airborne Position Message TYPE Code if Containment Radius is Available

Note: *If the position information comes from a GNSS receiver that conforms to the ARINC 743A characteristic, a suitable source of information for the containment radius (R_C), is ARINC 429 label 130 from that GNSS receiver.*

If R_C (containment radius) information is available from the navigation data source, then the transmitting ADS-B subsystem will determine the TYPE Code (the value of the TYPE subfield) of Airborne Position Messages as follows.

a. If current valid horizontal position information is not available to the ADS-B Transmitting Subsystem, then the TYPE Code subfield of Airborne Position Messages will be set to ZERO (0).

b. If valid horizontal position and barometric pressure altitude information are both available to the ADS-B Transmitting Subsystem, then the ADS-B Transmitting Subsystem will set the TYPE Code subfield of Airborne Position Messages to a value in the range from 9 to 18 in accordance with Table A-2.

c. If valid horizontal position information is available to the ADS-B Transmitting Subsystem, but valid barometric pressure altitude information is *not* available, and valid geometric altitude information *is* available, the ADS-B Transmitting Subsystem will set the TYPE Code subfield of Airborne Position Messages to a value in the range from 20 to 22 depending on the radius of containment (R_C) in accordance with Table A-2.

d. If valid horizontal position information is available to the ADS-B Transmitting Subsystem, but neither valid barometric altitude information nor valid geometric altitude information is available, the ADS-B Transmitting Subsystem will set the TYPE Code subfield in Airborne Position Messages to a value in the range from 9 to 18 depending on the radius of containment R_C in accordance with Table A-2. (In that case, the ALTITUDE subfield of the Airborne Position Messages would be set to all ZEROs in order to indicate that valid altitude information is not available.)

A.1.4.1.1.2 Airborne Position Message TYPE Code if Containment Radius is Not Available

If R_C (radius of containment) information is NOT available from the navigation data source, then the ADS-B Transmitting Subsystem will indicate NIC=0 by selecting a TYPE Code of 0, 18, or 22 in the Airborne Position Messages, as follows:

a. The ADS-B Transmitting Subsystem will set the TYPE Code subfield to ZERO (0) if valid horizontal position information is not available.

b. The ADS-B Transmitting Subsystem will set the TYPE Code subfield to 18 if valid pressure altitude information is available, or if neither valid pressure altitude nor valid geometric altitude information is available.

If valid pressure altitude is not available, but valid geometric altitude information is available, the ADS-B Transmitting Subsystem will set the TYPE Code subfield to 22.

A.1.4.1.2 Surface Position Message TYPE Code

A.1.4.1.2.1 Surface Position Message TYPE Code if Containment Radius is Available

If R_C (horizontal radius of containment) information is available from the navigation data source, then the ADS-B Transmitting Subsystem will use R_C to determine the TYPE Code used in the Surface Position Message in accordance with Table A-2.

Note: *If the position information comes from a GNSS receiver that conforms to the ARINC 743A characteristic, a suitable source of information for the containment radius (R_C), is ARINC 429 label 130 from that GNSS receiver.*

A.1.4.1.2.2 Surface Position Message TYPE Code if Radius of Containment is Not Available

If R_C (horizontal radius of containment) information is not available from the navigation data source, then the ADS-B Transmitting Subsystem will indicate NIC=0 by selecting a TYPE Code of 0 or 8 in the Surface Position Messages, as follows:

a. The ADS-B Transmitting Subsystem will set the TYPE Code subfield to ZERO (0) if valid horizontal position information is not available.

b. The ADS-B Transmitting Subsystem will set the TYPE Code subfield to 8 if valid horizontal position information is available. (This TYPE Code indicates that radius of containment, R_C, is either unknown or greater than or equal to 0.1 NM.)

A.1.4.1.2.3 TYPE Code based on Horizontal Protection Level or Estimated Horizontal Position Accuracy

a. If valid horizontal position information is available, then the "TYPE" Code in the Surface Position Message will be set in the range from "5" to "8."

b. If R_C (Horizontal Radius of Containment) information is available from the navigation data source, the "TYPE" Code will be selected according to the R_C value, in accordance with Table A-2.

c. If R_C is not available from the navigation data source, then the "TYPE" Code will be set to 8.

A.1.4.2 Airborne Position Format

The Airborne Position squitter will be formatted as specified in the definition of Register 05_{16} in Figure A-1.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.2.1 Compact Position Reporting (CPR) Format (F)

In order to achieve coding that is unambiguous world wide, CPR will use two format types, known as "**even**" and "**odd**." This one-bit field (ME bit 22, Message bit 54) **shall** be used to define the CPR Format (F) type. A CPR Format equal to ZERO (0) **shall** denote an "**even**" format coding, while a CPR Format equal to ONE (1) **shall** denote an "**odd**" format coding (§A.1.7.7).

A.1.4.2.2 Time Synchronization (T)

This one-bit field (ME bit 21, Message bit 53) will indicate whether or not the Time of Applicability of the message is synchronized with UTC time. "T" equal to ZERO (0) will denote that the time is not synchronized to UTC. "T" equal to ONE (1) will denote that Time of Applicability is synchronized to UTC time. Synchronization will only be used for Airborne Position Messages having the top two horizontal position precision categories (TYPE Codes 9, 10, 20 and 21).

When T=1, the time of validity in the Airborne Message format will be encoded in the 1-bit "F" field which (in addition to CPR format type) will indicate the 0.2 second time tick for UTC Time of Position Validity. The "F" bit will alternate between 0 and 1 for successive 0.2 second time ticks, beginning with F=0 when the Time of Applicability will be an exact even-numbered UTC second.

A.1.4.2.3 CPR Encoded Latitude/Longitude

The CPR Encoded Latitude/Longitude field in the Airborne Position Message will be a 34-bit field (ME bits 23 – 56, Message bits 55 – 88) containing the Latitude and Longitude of the Aircraft's Airborne Position. The Latitude and Longitude will each occupy 17 bits. The Airborne Latitude and Longitude encoding will contain Airborne CPR-encoded values in accordance with §A.1.7. The unambiguous range for the local decoding of Airborne Messages will be 666 km (360 NM). The positional accuracy maintained by the Airborne CPR encoding will be approximately 5.1 meters.

Notes:

1. *The Latitude/Longitude encoding is also a function of the CPR format value (the "F" bit) described above.*

2. *Although the positional accuracy of the airborne CPR encoding is approximately 5.1 meters in most cases, implementers should be aware that the longitude position accuracy may only be approximately 10.0 meters when the latitude is either –87.0 +/- 1.0 degrees, or +87 +/- 1.0 degrees.*

A.1.4.2.3.1 Extrapolating Position (When T=1)

If "T" is set to one, Airborne Position Messages with TYPE Codes 9, 10, 20 and 21 will have Times of Applicability that are exact 0.2 UTC second epochs. In that case, the "F" bit will be ZERO (0) if the Time of Applicability is an even-numbered 0.2 second UTC epoch, or ONE (1) if the Time of Applicability is an odd-numbered 0.2 second epoch.

Note 1: *Here, an "even-numbered 0.2 second epoch" means an epoch that occurs an even number of 200-millisecond time intervals after an even-numbered UTC second. An "odd-numbered 0.2 second epoch" means an epoch that occurs an odd number of 200-millisecond time intervals after an even-numbered UTC second. Examples of even-numbered 0.2 second UTC epochs are 12.0 s, 12.4 s, 12.8 s, 13.2 s, 13.6 s, etc. Examples of odd-numbered UTC epochs are 12.2 s, 12.6 s, 13.0 s, 13.4 s, 13.8 s, etc.*

The CPR-encoded Latitude and Longitude that are loaded into the Airborne Position register will comprise an estimate of the A/V position at the Time of Applicability of that Latitude and Longitude, which is an exact 0.2 second UTC epoch. The register will be loaded no earlier than 150 ms before the Time of Applicability of the data being loaded, and no later than 50 ms before the Time of Applicability of that data.

This timing ensures that the ADS-B Receiving Subsystem may easily recover the Time of Applicability of the data in the Airborne Position Message, as follows:

- If F=0, the Time of Applicability shall be the nearest even-numbered 0.2 second UTC epoch to the time that the Airborne Position Message is received.

- If F=1, the Time of Applicability shall be the nearest odd-numbered 0.2 second UTC epoch to the time that the Airborne Position Message is received.

Note 2: *If the Airborne Position register is loaded every 200 ms, the ideal time to load that register would be 100 ms before the Time of Applicability of the data being loaded. The register would then be re-loaded, with data applicable at the next subsequent 0.2 second UTC epoch, 100 ms before that next subsequent 0.2 second epoch. That way, the time of transmission of an Airborne Position Message would never differ by more than 100 ms from the Time of Applicability of the data in that message. By specifying "100 ms ± 50 ms" rather than 100 ms exactly, some tolerance is allowed for variations in implementation.*

The position data that is loaded into the Airborne Position register will be an estimate of the A/V position at the Time of Applicability.

Note 3: *The position may be estimated by extrapolating the position from the time of validity of the fix (included in the position fix) to the Time of Applicability of the data in the register (which, if T=1, is an exact 0.2 UTC time tick). This may be done by a simple linear extrapolation using the velocity provided with the position fix and the time difference between the position fix validity time and the Time of Applicability of the transmitted data. Alternatively, other methods of estimating the position, such as alpha-beta trackers or Kalman filters, may be used.*

Every 200 ms, the contents of the position registers will be updated by estimating the A/V position at the next subsequent 0.2 second UTC epoch. This process will continue with new position fixes as they become available from the source of navigation data.

A.1.4.2.3.2 Extrapolating Position (When T=0)

"T" will be set to ZERO (0) if the Time of Applicability of the data being loaded into the position register is not synchronized to any particular UTC epoch. In that case, the position register will be re-loaded with position data at intervals that are no more than 200 ms apart. The position being loaded into the register will have a Time of Applicability that is never more than 200 ms different from any time during which the register holds that data.

Note: *This may be accomplished by loading the Airborne Position register at intervals that are, on average, no more than 200 ms apart, with data for which the Time of Applicability is between the time the register is loaded and the time that it is loaded again. (Shorter intervals than 200 ms are permitted, but not required.)*

If "T" is ZERO (0), then ADS-B Receiving Subsystems will accept Airborne Position Messages as being current as of the Time of Receipt. The ADS-B Transmitting Subsystem will re-load the Airborne Position register with updated estimates of the A/V position, at intervals that are no more than 200 ms apart. The process will continue with new position reports as they become available.

A.1.4.2.3.3 Time-Out When New Position Data is Unavailable

In the event that the navigation input ceases, the extrapolation described in §A.1.4.2.3.1 and §A.1.4.2.3.2 will be limited to no more than two seconds. At the end of this timeout of two seconds, all fields of the Airborne Position register, except the altitude field, will be cleared (set to zero).

Note: *The altitude field, bits 9 to 20 of the register, would only be cleared if current altitude data were no longer available.*

With the appropriate register fields cleared, the ZERO TYPE Code field will serve to notify ADS-B Receiving Subsystems that the data in the Latitude and Longitude fields are invalid.

A.1.4.2.4 Altitude

This 12-bit field (ME bits 9 – 20, Message bits 41 – 52) will provide the aircraft altitude. Depending on the TYPE Code, this field will contain either:

1. Barometric altitude encoded in 25 or 100 foot increments (as indicated by the Q Bit) or,

2. GNSS height above ellipsoid (HAE).

Note: *GNSS altitude MSL is not accurate enough for use in the position report.*

A.1.4.2.5 NIC Supplement-B

The first 5-bit field (ME bits 1 – 5, Message bits 33 – 37) in every Mode S Extended Squitter Message contains the format TYPE Code. The format TYPE Code differentiates the 1090ES Messages into several classes: Airborne Position, Airborne Velocity, Surface Position, Identification and Category, Aircraft Intent, Aircraft Status, etc. In addition, the format TYPE Code also encodes the Navigation Integrity Category (NIC) value of the source used for the position report.

The NIC Supplement-B is a 1-bit (ME bit 8, Message bit 40) subfield in the Airborne Position Message that is use in conjunction with the TYPE Code and NIC value to allow surveillance applications to determine whether the reported geometric position has an acceptable level of integrity containment region for the intended use. The NIC integrity containment region is described horizontally using the radius of containment, R_C. The format TYPE Code also differentiates the Airborne Messages as to the type of their altitude measurements: barometric pressure altitude or GNSS height (HAE). The 5-bit encoding for format TYPE Code and related NIC values conforms to the definition contained in Table A-25. If an update has not been received from an on-board data source for the determination of the TYPE Code value based on the radius of containment within the past 5 seconds, then the TYPE Code value will be encoded to indicate that R_C is “Unknown.”

A.1.4.3 Surface Position Format

The Surface Position squitter will be formatted as specified in the definition of Register 06_{16} in Figure A-2.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.3.1 Movement

This 7-bit field (ME bits 6 – 12, Message bits 38 – 44) will provide information on the Ground Speed of the aircraft. A non-linear scale will be used as defined in the Table A-3, where speeds are given in km/h (kt).

Table A-3: Coding of the Movement Field

Coding (Decimal)	Meaning	Quantization
0	No Movement Information Available	
1	Aircraft Stopped (Ground Speed = 0 knots)	
2	0 knots < Ground Speed ≤ 0.2315 km/h (0.125 kt)	
3 - 8	0.2315 km/h (0.125 kt) < Ground Speed ≤ 1.852 km/h (1 kt)	0.2700833 km/h steps
9 - 12	1.852 km/h (1 kt) < Ground Speed ≤ 3.704 km/h (2 kt)	0.463 km /h (0.25 kt) steps
13 - 38	3.704 km/h (2 kt) < Ground Speed ≤ 27.78 km/h (15 kt)	0.926 km/h (0.50 kt) steps
39 - 93	27.78 km/h (15 kt) < Ground Speed ≤ 129.64 km/h (70 kt)	1.852 km/h (1.00 kt) steps
94 - 108	129.64 km/h (70 kt) < Ground Speed ≤ 185.2 km/h (100 kt)	3.704 km/h (2.00 kt) steps
109 - 123	185.2 km/h (100 kt) < Ground Speed ≤ 324.1 km/h (175 kt)	9.26 km/h (5.00 kt) steps
124	324.1 km/h (175 kt) < Ground Speed	
125	Reserved for Aircraft Decelerating	
126	Reserved for Aircraft Accelerating	
127	Reserved for Aircraft Backing-Up	

A.1.4.3.2 Heading

A.1.4.3.2.1 Heading/Ground Track Status

This one bit field (ME bit 13, Message bit 45) will define the validity of the Heading value. Coding for this field will be as follows: 0=not valid and 1= valid.

Note: *If a source of A/V Heading **is not** available to the ADS-B Transmitting Subsystem, but a source of Ground Track Angle **is** available, then Ground Track Angle may be used instead of Heading, provided that the STATUS BIT FOR HEADING subfield is set to ZERO (0) whenever the Ground Track Angle is not a reliable indication of the A/V's Heading. (The Ground Track Angle is not a reliable indication of the A/V's Heading when the A/V's Ground Speed is low.)*

A.1.4.3.2.2 Heading/Ground Track Value

This 7-bit field (ME bits 14 – 20, Message bits 46 – 52) will define the direction (in degrees clockwise from true or magnetic north) of aircraft motion on the surface. The Ground Track will be encoded as an unsigned Angular Weighted Binary numeral, with an MSB of 180 degrees and an LSB of 360/128 degrees, with ZERO (binary 000 0000) indicating a value of ZERO degrees. The data in the field will be rounded to the nearest multiple of 360/128 degrees.

Note: *The reference direction for Heading (whether True North or Magnetic North) is indicated in the Horizontal Reference Direction (HRD) field of the Aircraft Operational Status Message (§A.1.4.10.13).*

A.1.4.3.3 Compact Position Reporting (CPR) Format (F)

The one-bit (ME bit 22, Message bit 54) CPR Format (F) field for the Surface Position Message will be encoded as specified for the Airborne Position Message. That is, F = 0 will denote an "**even**" format coding, while F = 1 will denote an "**odd**" format coding (§A.1.7.7).

A.1.4.3.4 Time Synchronization (T)

This one-bit field (ME bit 21, Message bit 53) will indicate whether or not the Time of Applicability of the message is synchronized with UTC time. "T" equal to ZERO (0) will denote that the time is not synchronized to UTC. "T" equal to ONE (1) will denote that Time of Applicability is synchronized to UTC time. Synchronization will only be used for Surface Position Messages having the top two horizontal position precision categories (TYPE Codes 5 and 6).

When T=1, the time of validity in the Airborne Message format will be encoded in the 1-bit "F" field that (in addition to CPR format type) will indicate the 0.2 second time tick for UTC time of position validity. The "F" bit will alternate between ZERO (0) and ONE (1) for successive 0.2 second time ticks, beginning with F=0 when the Time of Applicability is an exact even-numbered UTC second.

A.1.4.3.5 CPR Encoded Latitude/Longitude

The CPR Encoded Latitude/Longitude field in the Surface Position Message will be a 34-bit field (ME bits 23 – 56, Message bits 55 – 88) containing the Latitude and Longitude coding of the Aircraft's Surface Position. The Latitude (*Y*) and Longitude (*X*) will each occupy 17 bits. The Surface Latitude and Longitude encoding will contain Surface CPR-encoded values in accordance with §A.1.7. The unambiguous range for local decoding of Surface Messages will be 166.5 km (90 NM). The positional accuracy maintained by the Surface CPR encoding will be approximately 1.25 meters.

Notes:

1. *The Latitude/Longitude encoding is also a function of the CPR format value (the "F" bit).*

2. *Although the positional accuracy of the surface CPR encoding is approximately 1.25 meters in most cases, implementers should be aware that the longitude position accuracy may only be approximately 3.0 meters when the latitude is either –87.0 ±1.0 degrees, or +87 ±1.0 degrees.*

A.1.4.3.5.1 Extrapolating Position (When T=1)

This extrapolation will conform to §A.1.4.2.3.1 (Substitute "surface" for "airborne" where appropriate).

A.1.4.3.5.2 Extrapolating Position (When T=0)

This extrapolation will conform to §A.1.4.2.3.2 (Substitute "surface" for "airborne" where appropriate).

A.1.4.3.5.3 Time-Out When New Position Data is Unavailable

This time-out will conform to §A.1.4.2.3.3 (Substitute "surface" for "airborne" where appropriate).

A.1.4.4 Identification and Category Format

The Identification and Category squitter will be formatted as specified in the definition of Register 08_{16} in Figure A-4.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.4.1 Aircraft Identification Coding

Note: *The coding of Aircraft Identification is defined in §2.2.19.1.13 of RTCA/DO-181D. It is reproduced here for convenience.*

Each character will be coded as a six-bit subset of the ICAO 7-unit coded character set (ICAO Annex 10, Vol. IV, §3.1.2.9.1.2, Table 3-9) as specified in the Table A-4. The character set will be transmitted with the most significant bit (MSB) first. The reported aircraft code will begin with character 1. Characters will be coded consecutively without an intervening SPACE code. Any unused character spaces at the end of the subfield will contain a SPACE character code.

Table A-4: Aircraft Identification Character Coding

				b_6	0	0	1	1
				b_5	0	1	0	1
b_4	b_3	b_2	b_1					
0	0	0	0			P	SP[1]	0
0	0	0	1		A	Q		1
0	0	1	0		B	R		2
0	0	1	1		C	S		3
0	1	0	0		D	T		4
0	1	0	1		E	U		5
0	1	1	0		F	V		6
0	1	1	1		G	W		7
1	0	0	0		H	X		8
1	0	0	1		I	Y		9
1	0	1	0		J	Z		
1	0	1	1		K			
1	1	0	0		L			
1	1	0	1		M			
1	1	1	0		N			
1	1	1	1		O			

[1]SP = SPACE code

A.1.4.5 Airborne Velocity Format

The Airborne Velocity squitter will be formatted as specified in the definition of Register 09_{16} in Figure A-5.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.5.1 Subtypes 1 and 2

Subtypes 1 and 2 of the Airborne Velocity format will be used when the transmitting aircraft's velocity over ground is known. Subtype 1 will be used for velocities under 1000 knots and Subtype 2 will be used for aircraft capable of supersonic flight when the velocity might exceed 1022 knots.

This message will not be broadcast if the only valid data is the Intent Change flag (§A.1.4.5.3). After initialization, broadcast will be suppressed by loading Register 09_{16} with ALL ZEROs and then discontinuing updating the register until data input is available again.

The supersonic version of the velocity coding will be used if either the East-West OR North-South velocities exceed 1022 knots. A switch to the normal velocity coding will be made if both the East-West AND North-South velocities drop below 1000 knots.

A.1.4.5.2 Subtypes 3 and 4

Subtypes 3 and 4 of the Airborne Velocity format will be used when the transmitting aircraft's velocity over ground is not known. These Subtypes will substitute Airspeed and Heading for the velocity over ground. Subtype 3 will be used at subsonic velocities, while Subtype 4 will be reserved for Airspeeds in excess of 1000 knots.

The Air Referenced Velocity is contained in the Airborne Velocity Subtypes 3 and 4, and the velocity information is required from only certain classes of ADS-B equipped aircraft.

Note: *Air Referenced Velocity Messages may be received from airborne aircraft that are also broadcasting messages containing ground referenced velocity information. ADS-B Receiving Subsystems conformant to these MOPS are required to receive and process ground referenced and Air Referenced Velocity Messages from the same aircraft and output the corresponding reports. Although not required in these MOPS, future versions of these MOPS will specify under what conditions both ground referenced and air referenced velocity would be transmitted. This is intended to provide compatibility with anticipated future requirements for the transmission of both types of velocity information.*

This Airborne Velocity Message will not be broadcast if the only valid data is the Intent Change flag (§A.1.4.5.3). After initialization, broadcast will be suppressed by loading Register 09_{16} with ALL ZEROs and then discontinuing updating the register until data input is available again.

The supersonic version of the Velocity Message coding will be used if the Airspeed exceeds 1022 knots. A switch to the normal velocity coding will be made if the Airspeed drops below 1000 knots.

A.1.4.5.3 Intent Change Flag in Airborne Velocity Messages

An Intent Change event will be triggered 4 seconds after the detection of new information being inserted in Registers 40_{16} to 42_{16}. The code will remain set for 18 ±1 seconds following an intent change.

Intent Change Flag coding:

0 = no change in intent
1 = intent change

Notes:

1. *Register 43_{16} is not included since it contains dynamic data that will be continuously changing.*

2. *A four-second delay is required to provide for settling time for intent data derived from manually set devices.*

A.1.4.5.4 HEADING TO BE DELETED – PREVIOUSLY "IFR Capability Flag"

A.1.4.5.5 Navigation Accuracy Category for Velocity (NAC_V)

This 3-bit (ME bits 11-13, Message bits 43-45) subfield will indicate the Navigation Accuracy Category for Velocity (NAC_V) as specified in Table A-5.

The ADS-B Transmitting Subsystem will accept, via an appropriate data interface, data from which the own-vehicle Navigation Accuracy Category for Velocity (NAC_V) may be determined, and it will use such data to establish the NAC_V subfields in transmitted ADS-B Airborne Velocity Messages.

If the external data source provides 95% accuracy figures of merit for horizontal and vertical velocity, then the ADS-B Transmitting Subsystem will determine the value of the NAC_V field in the Airborne Velocity Messages, Subtypes 1, 2, 3 and 4 according to Table A-5.

Table A-5: Determining NAC_V Based on Position Source Declared Horizontal Velocity Error

Navigation Accuracy Category for Velocity		
Coding		Horizontal Velocity Error
(Binary)	(Decimal)	
000	0	≥ 10 m/s
001	1	< 10 m/s
010	2	< 3 m/s
011	3	< 1 m/s
100	4	< 0.3 m/s

A.1.4.5.6 Heading in Airborne Velocity Messages

A.1.4.5.6.1 Heading Status

This one bit (ME bit 14, Message bit 46) subfield in Airborne Velocity Messages, Subtype 3 or 4 will define the availability of the Heading value. Coding for this field will be: 0 = not available and 1 = available.

A.1.4.5.6.2 Heading Value

This 10-bit (ME bits 15 – 24, Message bits 47 – 56) subfield in Airborne Velocity Messages, Subtype 3 or 4 will give the Aircraft Heading (in degrees clockwise from true or magnetic north) when velocity over ground is not available. The Heading will be encoded as an unsigned Angular Weighted Binary numeral with an MSB of 180 degrees and an LSB of 360/1024 degrees, with ALL ZEROs (binary 00 0000 0000) indicating a value of ZERO degrees. The data in the field will be rounded to the nearest multiple of 360/1024 degrees.

Note: *The reference direction for Heading (whether True North or Magnetic North) is indicated in the Horizontal Reference Direction (HRD) field of the Aircraft Operational Status Message (§A.1.4.10.13).*

A.1.4.5.7 Difference from Baro Altitude in Airborne Velocity Messages

This 8-bit (ME bits 49 – 56, Message bits 81 – 88) subfield will give the signed difference between barometric and GNSS altitude. (Coding for this field will be as indicated in Figure A-5 and Figure A-6).

If Airborne Position is being reported using Format TYPE Codes 9 or 10, only GNSS HAE will be used. For Format TYPE Codes 9 or 10, if GNSS HAE is not available, the field will be coded with ALL ZEROs. For Format TYPE Codes 11 through 18, either GNSS HAE or altitude MSL will be used. The basis for the Baro Altitude difference (either GNSS HAE or altitude MSL) will be used consistently for the reported difference.

Note: *The difference between Baro Altitude and GNSS height above ellipsoid (HAE) is preferred. However, GNSS altitude (MSL) may be used when Airborne Position is being reported using Format TYPE Codes 11 through 18.*

A.1.4.6 Aircraft Status Register Format

The Aircraft Status register will be formatted as specified in the definition of Register 07_{16} in Figure A-3.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.6.1 Purpose

Note: *Unlike the other Extended Squitter registers, the contents of this register are not broadcast. The purpose of this register is to serve as an interface between the transponder function and the General Formatter/Manager function (GFM, A.1.6). The two fields defined for this format are the Transmission Rate Subfield and the Altitude Type Subfield.*

A.1.4.6.2 Transmission Rate Subfield (TRS)

This field will only be used for a transponder implementation of Extended Squitter.

The TRS will be used to notify the transponder of the aircraft motion status while on the surface. If the aircraft is moving, the surface position squitter will be broadcast at a rate of twice per second, and identity squitters at a rate of once per 5 seconds. If the aircraft is stationary, the surface position squitter will be broadcast at a rate of once per 5 seconds and the identity squitter at a rate of once per 10 seconds.

The algorithm specified in the definition of Register 07_{16} will be used by the GFM (§A.1.6) to determine motion status and the appropriate code will be set in the TRS subfield. The transponder will examine the TRS subfield to determine which rate to use when it is broadcasting surface squitters.

A.1.4.6.3 Altitude Type Subfield (ATS)

This field will only be used for a transponder implementation of Extended Squitter.

Note: *The transponder normally loads the altitude field of the airborne position squitter from the same digital source as used for addressed replies. This is done to minimize the possibility that the altitude in the squitter is different from the altitude that would be obtained by direct interrogation.*

If the GFM (§A.1.6) inserts GNSS height (HAE) into the airborne position squitter, it will instruct the transponder not to insert the baro altitude into the altitude field. The ATS subfield will be used for this purpose.

A.1.4.7 Event-Driven Protocol

A message inserted in Register $0A_{16}$ (or an equivalent transmit register) will be broadcast once by the transponder at the earliest opportunity. Formats for messages using this protocol will be identical to those defined for Registers 61_{16} to $6F_{16}$ (see Figure A-7).

Note: *The GFM (§A.1.6) is responsible for ensuring pseudo-random timing, priority and for observing the maximum transmission rate for this register of 2 per second. Additional details are specified in §A.1.6.4 and in the following paragraphs.*

A.1.4.7.1 Purpose

Note: *The Event-Driven protocol is intended as a flexible means to support the broadcast of messages beyond those defined for position, velocity, and identification. These typically will be messages that are broadcast regularly for a period of time based on the occurrence of an event and/or having a variable broadcast rate as determined by processes external to the transponder. Two examples are: (1) the broadcast of Emergency/Priority Status at a periodic rate during a declared aircraft emergency, and (2) the broadcast of TCAS Resolution Advisory data during a declared event.*

A.1.4.7.2 TCAS Resolution Advisory (RA) Broadcast

The 1090ES TCAS RA Broadcast Message contains the same information as the RA message readout using the GICB protocol, including the aircraft ICAO 24-bit Address. A ground-based 1090ES receiver with an omni-directional receiving capability can provide TCAS RA Messages to the ground systems much sooner that with a scanning beam antenna. The TCAS RA information is defined as a Subtype=2 of the existing 1090ES Aircraft Status Message.

The airborne aircraft broadcast rates and priorities for the TCAS RA Broadcast Message are defined below and in ICAO Document 9871, §B.2.3.8.2. The format for broadcasting a 1090ES Aircraft Status Message with TCAS RA Message content (1090ES Message TYPE=28, Subtype=2) is defined here in Figure A-8b, and in ICAO Document 9871, Table B-2-97b.

A.1.4.7.2.1 Transmission Rate

The ADS-B Aircraft Status (TYPE=28) TCAS RA Broadcast Message (Subtype=2) will be broadcast starting within 0.5 seconds after the transponder notification of the initiation of a TCAS Resolution Advisory.

The ADS-B Aircraft Status (TYPE=28) TCAS RA Broadcast Message (Subtype=2) will be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds for the duration of the TCAS Resolution Advisory.

A.1.4.7.2.2 Message Delivery

ADS-B Aircraft Status TCAS RA Broadcast Message delivery is accomplished using the Event-Driven protocol. The broadcast of the TCAS RA Broadcast Message will be terminated 24 ±1 seconds after the Resolution Advisory Termination (RAT) flag (see ICAO Annex 10, Volume IV, §4.3.8.4.2.2.1.3) transitions from ZERO (0) to ONE (1). The broadcast of the ADS-B Aircraft Status TCAS RA Broadcast Message takes priority over the Emergency/Priority Status broadcast, and all other Event-Driven Message types, as specified in §A.1.6.4.3.

A.1.4.8 Emergency/Priority Status

Register 61_{16} contains an exact bit-for-bit duplication of the Emergency/Priority Status information that is broadcast using an Event-Driven Aircraft Status Extended Squitter Message (TYPE=28 and Subtype=1). Subtype=1 is used specifically to provide Emergency/Priority Status information and the broadcast of the Mode A (4096) Code. The contents of Register 61_{16} will be formatted as specified in Figure A-8a.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.8.1 Transmission Rate

The Aircraft Status (TYPE=28) Emergency/Priority Status ADS-B Message (Subtype=1) will be broadcast using the Event–Driven protocol. The rate of transmission varies depending on other conditions. If the transmission of the Mode A Code is disabled, the transmission of the "Emergency/Priority Status Message" occurs only when an emergency condition is active. When the transmission of the Mode A Code is enabled, the transmission rate of the "Emergency/Priority Status Message" depends on whether the Mode A Code is changed, or if an emergency condition is active.

When the Mode A Code is set to "3000," the 1090ES Transmitting Subsystem will disable the transmission of the Mode A Code and broadcast the "Emergency/Priority Message" in accordance with §A.1.4.8.1.1 only when an emergency is declared. Otherwise, the Mode A Code transmission is enabled and the broadcast rates of §A.1.4.8.1.2 apply.

Note: *The use of Mode A Code "3000" for this purpose is in accordance with the ICAO Doc 9871 provision to disable the transmission of the Mode A Code on 1090ES. This will occur at such time that the ATC systems no longer depend on the Mode A Code to identify aircraft.*

A.1.4.8.1.1 "Emergency/Priority Status Message" Broadcast Rates When Transmission of Mode A Code is Disabled

When the Mode A Code transmission is disabled as per §A.1.4.8.1, the following transmit rates apply:

a. The "Emergency/Priority Status Message" (TYPE=28, Subtype=1) will be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds relative to the previous "Emergency/Priority Status" for the duration of the emergency condition which is established by any value other than ZERO in the "Emergency/Priority Status" subfield.

b. In the case where there is no emergency condition established by a ZERO value in the "Emergency/Priority Status" subfield, then the "Emergency/Priority Status Message" will not be broadcast.

A.1.4.8.1.2 Emergency/Priority Status Message" Broadcast Rates When Transmission of Mode A Code is Enabled

When the Mode A Code transmission is enabled as per §A.1.4.8.1, the following transmit rates apply:

a. The "Emergency/Priority Status" (TYPE=28, Subtype=1) will be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds relative to the previous "Emergency/Priority Status" under the following conditions:

   i. For a duration of 24 ±1 seconds following a Mode A Code change by the pilot except if the Mode A Code is changed to 7500, 7600 or 7700.

   Note: *The case where the Mode A Code is set to 7500, 7600 or 7700, the transmission of the emergency condition is covered by ii. below. Setting the Mode A Code to 7500, 7600 or 7700 is indicated by a Permanent Alert in the "Surveillance Status" field (value of 1) (see §2.2.3.2.3.2). A change in the Mode A Code, except to 7500, 7600 or 7700, is indicated by a Temporary Alert in the "Surveillance Status" subfield (value of 2) (see §2.2.3.2.3.2).*

   ii. For the duration of an emergency condition by any non-ZERO value in the "Emergency/Priority Status" subfield, if the emergency code is cleared by the pilot changing the Mode A Code to other than 7500, 7600 or 7700, the broadcast of the "Emergency/Priority Status" Message will be continued for 24 ±1 seconds as "i" above.

b. In the absence of conditions specified in "a" above, the "Emergency/Priority Status" Message will be broadcast at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds relative to the previous "Emergency / Priority Status" Message.

A.1.4.8.2 Message Delivery

The Aircraft Status (TYPE=28) Emergency/Priority Status (Subtype=1) Message delivery will be accomplished using the Event-Driven protocol (§A.1.4.7). The broadcast of this message takes priority over the Event-Driven protocol broadcasts of all other message types, except for the ADS-B Aircraft Status TCAS RA Broadcast Message (TYPE=28, Subtype=2), which takes priority over the Emergency/Priority Status broadcast, and all other Event-Driven Message types, as specified in §A.1.6.4.3.

A.1.4.9 Target State and Status Information

Register 62_{16} contains an exact bit-for-bit duplicate of the Target State and Status Extended Squitter Message (TYPE=29 and Subtype=1), and will be formatted as specified in Figure A-9b.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.9.1 Transmission Rate

This message will be broadcast at random intervals uniformly distributed over the range of 1.2 to 1.3 seconds for the duration of the operation.

A.1.4.9.2 Source Integrity Level (SIL) Supplement

The "SIL Supplement" (Source Integrity Level Supplement) subfield is a 1-bit ("ME" bit 8, Message bit 40) field that defines whether the reported SIL probability is based on a "per hour" probability or a "per sample" probability as defined in Table A-6.

Table A-6: "SIL Supplement" Subfield Encoding

Coding	Meaning
0	Probability of exceeding NIC radius of containment is based on "per hour"
1	Probability of exceeding NIC radius of containment is based on "per sample"

► **Per Hour:** The probability of the reported geometric position laying outside the NIC containment radius in any given hour without an alert or an alert longer than the allowable time-to-alert. The per hour representation will typically be used when the probability of exceeding the NIC is greater for the faulted versus fault-free Signal-in-Space case (When the Signal-in-Space fault rate is defined as hourly).

Note: *The probability of exceeding the integrity radius of containment for GNSS position sources are based on a per hour basis, as the NIC will be derived from the GNSS Horizontal Protection Level (HPL) which is based on a probability of* $1X10^{-7}$ *per hour.*

► **Per Sample:** The probability of a reported geometric position laying outside the NIC containment radius. The per sample representation will typically be used when the probability of exceeding the NIC is greater for the fault-free Signal-in-Space case, or when the position source does not depend on a Signal-in-Space.

Note: *The probability of exceeding the integrity radius of containment for IRU, DME/DME and DME/DME/LOC position sources may be based on a per sample basis.*

A.1.4.9.3 Selected Altitude Type

The "Selected Altitude Type" subfield is a 1-bit ("ME" bit 9, Message bit 41) field that will be used to indicate the source of Selected Altitude data that is being used to encode "ME" bits 10 through 20 (Message bits 42 through 52). Encoding of the "Selected Altitude Type" is defined in Table A-7. Whenever there is no valid MCP / FCU or FMS Selected Altitude data available, then the "Selected Altitude Type" subfield is set to ZERO (0).

Table A-7: "Selected Altitude Type" Subfield Encoding

Coding	Meaning
0	Data being used to encode "ME" bits 10 through 20 is derived from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment.
1	Data being used to encode "ME" bits 10 through 20 is derived from the Flight Management System (FMS).

A.1.4.9.4 MCP/FCU Selected Altitude or FMS Selected Altitude

a. The "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield is an 11-bit ("ME" bits 10 through 20, Message bits 42 through 52) field that contains either "MCP / FCU Selected Altitude" or "FMS Selected Altitude" data in accordance with the following subparagraphs.

b. Whenever valid Selected Altitude data is available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, such data will be used to encode "ME" bits 10 through 20 (Message bits 42 through 52) in accordance with Table A-8. Use of MCP / FCU Selected Altitude is then declared in the "Selected Altitude Type" subfield as specified in Table A-7.

c. Whenever valid Selected Altitude data is NOT available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, but valid Selected Altitude data is available from the Flight Management System (FMS), then the FMS Selected Altitude data is used to encode "ME" bits 10 through 20 (Message bits 42 through 52) in accordance with Table A-8. Use of FMS Selected Altitude is then declared in the "Selected Altitude Type" subfield as specified in Table A-7.

d. Encoding of Selected Altitude data in "ME" bits 10 through 20 (Message bits 42 through 52) is in accordance with Table A-8. Encoding of the data is rounded so as to preserve accuracy of the source data within ±½ LSB.

e. Whenever there is NO valid MCP / FCU or FMS Selected Altitude data available, then the "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield ("ME" bits 10 through 20, Message bits 42 through 52) will be set to ZERO (0) as indicated in Table A-8.

Table A-8: "MCP/FCU Selected Altitude or FMS Selected Altitude" Subfield Encoding

Coding ("ME" bits 10 ---- 20)		Meaning
(Binary)	(Decimal)	
000 0000 0000	0	**NO Data *or* INVALID Data**
000 0000 0001	1	0 feet
000 0000 0010	2	32 feet
000 0000 0011	3	64 feet
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
111 1111 1110	2046	65440 feet
111 1111 1111	2047	65472 feet

A.1.4.9.5 Barometric Pressure Setting (Minus 800 millibars)

a. The "Barometric Pressure Setting (Minus 800 millibars)" subfield is a 9-bit ("ME" bits 21 through 29, Message bits 53 through 61) field that contains Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source.

b. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting is encoded in "ME" bits 21 through 29 (Message bits 53 through 61) in accordance with Table A-9.

c. Encoding of Barometric Pressure Setting data in "ME" bits 21 through 29 (Message bits 53 through 61) will be rounded so as to preserve a reporting accuracy within ±½ LSB.

d. Whenever there is NO valid Barometric Pressure Setting data available, then the "Barometric Pressure Setting (Minus 800 millibars) subfield ("ME" bits 21 through 29, Message bits 53 through- 1) will be set to ZERO (0) as indicated in Table A-9.

e. Whenever the Barometric Pressure Setting data is greater than 1209.5 or less than 800 millibars, then the "Barometric Pressure Setting (Minus 800 millibars) subfield ("ME" bits 21 through 29, Message bits 53 through 61) will be set to ZERO (0).

Table A-9: "Barometric Pressure Setting (Minus 800 millibars)" Subfield Encoding

Coding ("ME" bits 21 ---- 29)		Meaning
(Binary)	(Decimal)	
0 0000 0000	0	**NO Data *or* INVALID Data**
0 0000 0001	1	0 millibars
0 0000 0010	2	0.8 millibars
0 0000 0011	3	1.6 millibars
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
1 1111 1110	510	407.2 millibars
1 1111 1111	511	408.0 millibars

A.1.4.9.6 Selected Heading Status

The "Selected Heading Status" subfield is a 1-bit ("ME" bit 30, Message bit 62) field that will be used to indicate the status of Selected Heading data that is being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) in accordance with Table A-10.

Table A-10: "Selected Heading Status" Subfield Encoding

Coding ("ME" bit 30)	Meaning
0	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is either **NOT** Available or is **INVALID**. See Table A-12.
1	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is Available and is **VALID**. See Table A-12.

A.1.4.9.7 Selected Heading Sign

The "Selected Heading Sign" subfield is a 1-bit ("ME" bit 31, Message bit 63) field that will be used to indicate the arithmetic sign of Selected Heading data that is being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) in accordance with Table A-11.

Table A-11: "Selected Heading Sign" Subfield Encoding

Coding ("ME" bit 31)	Meaning
0	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is Positive in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is positive or Zero for all values that are less than 180 degrees). See Table A-12.
1	Data being used to encode "ME" bits 32 through 39 (Message bits 64 through 71) is Negative in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is ONE for all values that are greater than 180 degrees). See Table A-12.

A.1.4.9.8 Selected Heading

a. The "Selected Heading" subfield is an 8-bit ("ME" bits 32 through 39, Message bits 64 through 71) field that contains Selected Heading data encoded in accordance with Table A-12.

b. Encoding of Selected Heading data in "ME" bits 31 through 39 (Message bits 63 through 71) will be rounded so as to preserve accuracy of the source data within ±½ LSB.

c. Whenever there is NO valid Selected Heading data available, then the Selected Heading Status, Sign, and Data subfields ("ME" bits 30 through 39, Message bits 62 through 71) will be set to ZERO (0) as indicated in Table A-12.

Table A-12: "Selected Heading Status, Sign and Data" Subfields Encoding

"ME" Bit Coding			Meaning
30	31	32 -------- 39	
Status	**Sign**	**Data**	
0	0	0000 0000	**NO Data *or* INVALID Data**
1	0	0000 0000	0.0 degrees
1	0	0000 0001	0.703125 degrees
1	0	0000 0010	1.406250 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	0	1111 1111	179.296875 degrees
1	1	0000 0000	180.0 or -180.0 degrees
1	1	0000 0001	180.703125 or -179.296875 degrees
1	1	0000 0010	181.406250 or -178.593750 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	1	1000 0000	270.000 or -90.0000 degrees
1	1	1000 0001	270.703125 or -89.296875 degrees
1	1	1000 0010	271.406250 or -88.593750 degrees
1	1	1111 1110	358.593750 or -1.4062500 degrees
1	1	1111 1111	359.296875 or -0.7031250 degrees

A.1.4.9.9 Navigation Accuracy Category for Position (NAC_P)

This 4-bit (ME bits 40 – 43, Message bits 72 – 75) subfield will be used to indicate the Navigational Accuracy Category of the navigation information used as the basis for the aircraft reported position. The NAC_P subfield will be encoded as shown in Table A-15. If an update has not been received from an on-board data source for NAC_P within the past 5 seconds, then the NAC_P subfield will be encoded as a value indicating "Unknown Accuracy."

Table A-15: Encoding of Navigation Accuracy Category for Position (NAC_P)

Coding (Binary)	Coding (Decimal)	Meaning = 95% Horizontal Accuracy Bounds (EPU)
0000	0	EPU ≥ 18.52 km (10 NM) - Unknown accuracy
0001	1	EPU < 18.52 km (10 NM) - RNP-10 accuracy
0010	2	EPU < 7.408 km (4 NM) - RNP-4 accuracy
0011	3	EPU < 3.704 km (2 NM) - RNP-2 accuracy
0100	4	EPU < 1852 m (1NM) - RNP-1 accuracy
0101	5	EPU < 926 m (0.5 NM) - RNP-0.5 accuracy
0110	6	EPU < 555.6 m (0.3 NM) - RNP-0.3 accuracy
0111	7	EPU < 185.2 m (0.1 NM) - RNP-0.1 accuracy
1000	8	EPU < 92.6 m (0.05 NM) - e.g., GPS (with SA)
1001	9	EPU < 30 m - e.g., GPS (SA off)
1010	10	EPU < 10 m - e.g., WAAS
1011	11	EPU < 3 m - e.g., LAAS
1100 - 1111	12 - 15	Reserved

Notes:

1. *The Estimated Position Uncertainty (EPU) used in the table is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position lying outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

2. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

A.1.4.9.10 Navigation Integrity Category for Baro (NIC_{BARO})

This 1-bit (ME bit 44, Message bit 76) subfield will be used to indicate whether or not the barometric pressure altitude being reported in the Airborne Position Message (§A.1.4.2) has been cross-checked against another source of pressure altitude. The NIC_{BARO} subfield will be encoded as shown in Table A-16. If an update has not been received from an on-board data source for NIC_{BARO} within the past 5 seconds, then the NIC_{BARO} subfield will be encoded as a value of ZERO (0).

Table A-16: NIC_{BARO} Encoding

Coding	Meaning
0	The barometric altitude that is being reported in the Airborne Position Message is based on a Gilham coded input that has not been cross-checked against another source of pressure altitude
1	The barometric altitude that is being reported in the Airborne Position Message is either based on a Gilham code input that has been cross-checked against another source of pressure altitude and verified as being consistent, or is based on a non-Gilham coded source

Notes:

1. *The barometric altitude value itself is conveyed within the ADS-B Position Message.*

2. *The NIC_{BARO} subfield provides a method of indicating a level of data integrity for aircraft installed with Gilham encoding barometric altitude sources. Because of the potential of an undetected error when using a Gilham encoded altitude source, a comparison will be performed with a second source and only if the two sources agree will the NIC_{BARO} subfield be set to a value of "1". For other barometric altitude sources (Synchro or DADS) the integrity of the data is indicated with a validity flag or SSM. No additional checks or comparisons are necessary. For these sources the NIC_{BARO} subfield will be set to a value of "1" whenever the barometric altitude is valid.*

3. *The use of Gilham type altimeters is strongly discouraged because of the potential for undetected altitude errors.*

A.1.4.9.11 Source Integrity Level (SIL)

This 2-bit (ME bits 45 – 46, Message bits 77 – 78) subfield will be used to define the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. The SIL will address the Signal-in-Space, if applicable, and will be the higher of the faulted or fault free probability of the Signal-In-Space causing the NIC radius of containment to be exceeded.

Note: *The faulted Signal-in-Space case will represent the highest probability for GNSS position sources while the fault free Signal-in-Space case will represent the highest probability for DME/DME or DME/DME/LOC position sources because the Signal-in-Space is monitored and for IRU position sources because there is no Signal-in-Space.*

The SIL probability can be defined as either "per sample" or "per hour" as defined in the SIL Supplement (SIL_{SUPP}) in §A.1.4.9.2.

The "SIL" subfield is encoded in accordance with Table A-17. For installations where the SIL value is being dynamically updated, if an update has not been received from an on-board data source for SIL within the past 5 seconds, then the SIL subfield will be encoded as a value of ZERO (0), indicating "Unknown."

Table A-17: Source Integrity Level (SIL) Encoding

SIL Coding		Probability of Exceeding the NIC Containment Radius (R_C)
(Binary)	(Decimal)	
00	0	Unknown or > 1 x 10^{-3} per flight hour or per sample
01	1	$\leq 1 \times 10^{-3}$ per flight hour or per sample
10	2	$\leq 1 \times 10^{-5}$ per flight hour or per sample
11	3	$\leq 1 \times 10^{-7}$ per flight hour or per sample

Note: *Implementers should not arbitrarily set the SIL to ZERO (0) just because SIL is not provided by the position source. Implementers should perform an off-line analysis of the installed position source to determine the appropriate SIL.*

A.1.4.9.12 Status of MCP/FCU Mode Bits

The "Status of MCP / FCU Mode Bits" subfield is a 1-bit ("ME" bit 47, Message bit 79) field that will be used to indicate whether the mode bits ("ME" bits 48, 49, 50 and 52, Message bits 80, 81, 82 and 84) are actively being populated (e.g., set) in the Target State and Status Message in accordance with Table A-18.

If information is provided to the ADS-B Transmitting Subsystem to set either "ME" bit 48, 49, 50, or 52 (Message bit 80, 81, 82 or 84) to either "0" or "1," then bit 47 will be set to ONE (1). Otherwise, bit 47 will be set to ZERO (0).

Table A-18: "Status of MCP/FCU Mode Bits" Subfield Encoding

Coding ("ME" Bit 47)	**Meaning**
0	No Mode Information is being provided in "ME" bits 48, 49, 50 or 52 (Message bits 80, 81, 82, or 84)
1	Mode Information is deliberately being provided in "ME" bits 48, 49, 50 or 52 (Message bits 80, 81, 82, or 84)

A.1.4.9.13 Autopilot Engaged

The "Autopilot Engaged" subfield is a 1-bit ("ME" bit 48, Message bit 80) field that will be used to indicate whether the autopilot system is engaged or not.

a. The ADS-B Transmitting Subsystem will accept information from an appropriate interface that indicates whether or not the Autopilot is engaged.

b. The ADS-B Transmitting Subsystem will set "ME" bit 48 (Message bit 80) in accordance with Table A-19.

Table A-19: "Autopilot Engaged" Subfield Encoding

Coding ("ME" Bit 48)	**Meaning**
0	Autopilot is NOT Engaged (e.g., not actively coupled and flying the aircraft)
1	Autopilot is Engaged (e.g., actively coupled and flying the aircraft)

A.1.4.9.14 VNAV Mode Engaged

The "VNAV Mode Engaged" subfield is a 1-bit ("ME" bit 49, Message bit 81) field that will be used to indicate whether the Vertical Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem will accept information from an appropriate interface that indicates whether or not the Vertical Navigation Mode is active.

b. The ADS-B Transmitting Subsystem will set "ME" bit 49 (Message bit 81) in accordance with Table A.1.4.9.14.

Table A.1.4.9.14: "VNAV Engaged" Subfield Encoding

Coding ("ME" Bit 49)	**Meaning**
0	VNAV Mode is NOT Active
1	VNAV Mode is Active

A.1.4.9.15 Altitude Hold Mode

The "Altitude Hold Mode" subfield is a 1-bit ("ME" bit 50, Message bit 82) field that will be used to indicate whether the Altitude Hold Mode is active or not.

a. The ADS-B Transmitting Subsystem will accept information from an appropriate interface that indicates whether or not the Altitude Hold Mode is active.

b. The ADS-B Transmitting Subsystem will set "ME" bit 50 (Message bit 82) in accordance with Table A.1.4.9.15.

Table A.1.4.9.15: "Altitude Hold Mode" Subfield Encoding

Coding ("ME" Bit 50)	**Meaning**
0	Altitude Hold Mode is NOT Active
1	Altitude Hold Mode is Active

A.1.4.9.16 Reserved for ADS-R Flag

The "Reserved for ADS-R Flag" subfield is a 1-bit ("ME" bit 51, Message bit 83) field that shall be used as specified in §2.2.18.4.6.

A.1.4.9.17 Approach Mode

The "Approach Mode" subfield is a 1-bit ("ME" bit 52, Message bit 84) field that will be used to indicate whether the Approach Mode is active or not.

a. The ADS-B Transmitting Subsystem will accept information from an appropriate interface that indicates whether or not the Approach Mode is active.

b. The ADS-B Transmitting Subsystem will set "ME" bit 52 (Message bit 84) in accordance with Table A.1.4.9.17.

Table A.1.4.9.17: "Approach Mode" Subfield Encoding

Coding ("ME" Bit 52)	**Meaning**
0	Approach Mode is NOT Active
1	Approach Mode is Active

A.1.4.9.18 TCAS/ACAS Operational

The "TCAS/ACAS Operational" subfield is a 1-bit ("ME" bit 53, Message bit 85) field that will be used to indicate whether the TCAS/ACAS System is Operational or not.

a. The ADS-B Transmitting Subsystem will accept information from an appropriate interface that indicates whether or not the TCAS/ACAS System is Operational.

b. The ADS-B Transmitting Subsystem will set "ME" bit 53 (Message bit 85) in accordance with Table A.1.4.9.18.

Table A.1.4.9.18: "TCAS/ACAS Operational" Subfield Encoding

Coding ("ME" Bit 53)	**Meaning**
0	TCAS/ACAS System is NOT Operational
1	TCAS/ACAS System IS Operational

Note: *As a reference point, RTCA DO-181D Mode-S Transponders consider that the TCAS/ACAS System is operational when "MB" bit 16 of Register 10_{16} is set to "ONE" (1). This occurs when the transponder / TCAS/ACAS interface is operational and the transponder is receiving TCAS/ACAS RI=2, 3 or 4. (Refer to RTCA DO-181D [EUROCAE ED-73C], Appendix B, Table B-3-16.*

A.1.4.10 Aircraft Operational Status Message

Register 65_{16} contains an exact bit-for-bit duplicate of the Aircraft Operational Status Message Extended Squitter (TYPE=31 and Subtype=0). The contents of the Aircraft Operational Status Message will be formatted as specified Figure A-10.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.10.1 Transmission Rate

The Aircraft Operational Status (TYPE=31 and Subtype=0, for airborne participants) ADS-B Message will be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds when the Target State and Status Message (TYPE=29 and Subtype=1) is not being broadcast and there has been a change within the past 24 ±1 seconds for value of any of the following message parameters:

a. TCAS/ACAS Operational

b. ACAS/TCAS resolution advisory active

c. NAC_P

d. SIL

Otherwise the Aircraft Operational Status (TYPE= 31 and Subtype=0, for airborne participants) ADS-B Message will be broadcast at random intervals that are uniformly distributed over the range of 2.4 to 2.6 seconds.

A.1.4.10.2 Message Delivery

Message delivery will be accomplished using the Event-Driven protocol (§A.1.4.7).

A.1.4.10.3 Capability Class (CC) Codes

This 16-bit (ME bits 9 – 24, Message bits 41 – 56) subfield in the Airborne Aircraft Operational Status Message (Subtype=0) or 12-bit (ME bits 9 – 20, Message bits 41 – 52) subfield in the Surface Aircraft Operational Status Message (Subtype=1) will be used to report the operational capability of the aircraft. Encoding of the CC subfield will be defined as specified in Table A-21 and Table A-22.

For an ADS-B Transmitting Subsystem compliant with DO-260B, if an update has not been received from an on-board data source within the past 5 seconds for any data element of the Capability Class Codes subfield, then the data associated with that data element will be considered invalid and so reflected in the encoding of that message element to reflect "No Capability" or "Unknown" capability.

Table A-21: Airborne Capability Class (CC) Code for Version 2 Systems

Msg Bit #	41	42	43	44	45	46	47	48	49	50	51	52 -- 56
"ME" Bit #	9	10	11	12	13	14	15	16	17	18	19	20 -- 24
Content	**Reserved** = 0,0		**TCAS Operational**	**1090ES IN**	**Reserved** = 0,0		**ARV**	**TS**	**TC**		**UAT IN**	**Reserved [6]**
	0,1		Reserved									
	1,0		Reserved									
	1,1		Reserved									

Subfield Coding:

1. TCAS Operational
   = 0: TCAS/ACAS is NOT Operational
   = 1: TCAS/ACAS IS Operational

2. 1090ES IN (1090 MHz Extended Squitter)
   = 0: Aircraft has NO 1090ES Receive capability
   = 1: Aircraft has 1090ES Receive capability

3. ARV (Air-Referenced Velocity Report Capability)
   = 0: No capability for sending messages to support Air Referenced Velocity Reports

= 1: Capability of sending messages to support Air-Referenced Velocity Reports.

4. TS (Target State Report Capability)
   = 0: No capability for sending messages to support Target State Reports
   = 1: Capability of sending messages to support Target State Reports

5. TC (Target Change Report Capability)
   = 0: No capability for sending messages to support Trajectory Change Reports
   = 1: Capability of sending messages to support TC+0 Report only
   = 2: Capability of sending information for multiple TC reports
   = 3: Reserved

6. UAT IN (Universal Access Transceiver)
   = 0: Aircraft has No UAT Receive capability
   = 1: Aircraft has UAT Receive capability

Table A-22: Surface Capability Class (CC) Code for Version 2 Systems

Msg Bit #	41	42	43	44	45	46	47	48	49 --- 51	52
"ME" Bit #	9	10	11	12	13	14	15	16	17 --- 19	20
Content	**Reserved** = 0,0		**POA**	**1090ES IN**	**Reserved** = 0,0		**B2 Low**	**UAT IN**	**NAC_V [3]**	**NIC Supplement-C [1]**
	0,1		Reserved							
	1,0		Reserved							
	1,1		Reserved							

Subfield Coding:

1. POA (Position Offset Applied)
   = 0: Position transmitted is not the ADS-B position reference point
   = 1: Position transmitted is the ADS-B position reference point

2. 1090ES IN (1090 MHz Extended Squitter)
   = 0: Aircraft has NO 1090ES Receive capability
   = 1: Aircraft has 1090ES Receive capability

3. B2 Low (Class B2 Transmit Power Less Than 70 Watts)
   = 0: Greater than or equal to 70 Watts Transmit Power
   = 1: Less than 70 Watts Transmit Power

4. UAT IN (Universal Access Transceiver)
   = 0: Aircraft has NO UAT Receive capability
   = 1: Aircraft has UAT Receive capability

5. NAC_V (Navigation Accuracy Category for Velocity)

6. NIC Supplement-C (NIC Supplement for use on the Surface)

A.1.4.10.4 Operational Mode (OM)

This 16-bit (ME bits 25 – 40, Message bits 57 – 72) subfield will be used to indicate the Operational Modes that are active on board the aircraft. Encoding of the OM subfield for Airborne Operational Status Messages (Subtype=0) will be as shown in Table A-23A. Encoding of the OM subfield for Surface Operational Status Messages (Subtype=1) will be as shown in Table A-23B.

Table A-23A: Airborne Operational Mode (OM) Subfield Format

Msg Bit #	57	58	59	60	61	62	63 -- 64	65 --- 72
"ME" Bit #	25	26	27	28	29	30	31 -- 32	33 --- 40
OM Format	0 0		**TCAS RA Active [1]**	**IDENT Switch Active [1]**	**Reserved for Receiving ATC Services [1]**	**Single Antenna Flag [1]**	**System Design Assurance [2]**	**Reserved [8]**
	0 1		Reserved					
	1 0		Reserved					
	1 1		Reserved					

Subfield Coding:

1. TCAS Resolution Advisory (RA) Active
   = 0: TCAS II or ACAS RA **not** active
   = 1: TCAS RA is active

2. IDENT Switch Active
   = 0: Ident switch not active
   = 1: Ident switch active – retained for 18 ±1 seconds

3. Reserved for Receiving ATC Services
   = 0: Set to ZERO for this version of these MOPS

4. Single Antenna Flag
   = 0: Systems with two functioning antennas
   = 1: Systems that use only one antenna

5. System Design Assurance (SDA)
   (see Table A.1.4.10.14)

Table A-23B: Surface Operational Mode (OM) Subfield Format

Msg Bit #	57	58	59	60	61	62	63 -- 64	65 --- 72
"ME" Bit #	25	26	27	28	29	30	31 -- 32	33 --- 40
OM Format	0 0		**TCAS RA Active [1]**	**IDENT Switch Active [1]**	**Reserved for Receiving ATC Services [1]**	**Single Antenna Flag [1]**	**System Design Assurance [2]**	**GPS Antenna Offset [8]**
	0 1		Reserved					
	1 0		Reserved					
	1 1		Reserved					

Subfield Coding:

1. TCAS Resolution Advisory (RA) Active
   = 0: TCAS II or ACAS RA **not** active
   = 1: TCAS RA is active

2. IDENT Switch Active
   = 0: Ident switch not active
   = 1: Ident switch active – retained for 18 ±1 seconds

3. Reserved for Receiving ATC Services
   = 0: Set to ZERO for this version of these MOPS

4. Single Antenna Flag
   = 0: Systems with two functioning antennas
   = 1: Systems that use only one antenna

5. System Design Assurance (SDA)
   (see Table A.1.4.10.14)

6. GPS Antenna Offset
   (see Table A.1.4.10.21A and Table A.1.4.10.21B)

A.1.4.10.5 Version Number

This 3-bit (ME bits 41 – 43, Message bits 73 – 75) subfield will be used indicate the Version Number of the formats and protocols in use on the aircraft installation. Encoding of the subfield will be as shown in Table A-24.

Table A-24: Version Number Encoding

VERSION NUMBER SUBFIELD		
Coding		**Meaning**
(Binary)	**(Decimal)**	
000	0	Conformant to DO-260 and DO-242
001	1	Conformant to DO-260A and DO-242A
010	2	Conformant to DO-260B and DO-242B
011 – 111	3 – 7	Reserved

A.1.4.10.6 Navigation Integrity Category (NIC) and NIC Supplement-A

The first 5-bit field (ME bits 1 – 5, Message bits 33 – 37) in every Mode S Extended Squitter Message contains the format TYPE Code. The format TYPE Code differentiates the 1090ES Messages into several classes: Airborne Position, Airborne Velocity, Surface Position, Identification and Category, Aircraft Intent, Aircraft Status, etc. In addition, the format TYPE Code also encodes the Navigation Integrity Category (NIC) value of the source used for the position report.

The NIC Supplement-A is a 1-bit (ME bit 44, Message bit 76) subfield in the Aircraft Operational Status Message that is use in conjunction with the TYPE Code and NIC value to allow surveillance applications to determine whether the reported geometric position has an acceptable level of integrity containment region for the intended use. The NIC integrity containment region is described horizontally using the radius of containment, R_C. The format TYPE Code also differentiates the Airborne Messages as to the type of their altitude measurements: barometric pressure altitude or GNSS height (HAE). The 5-bit encoding for format TYPE Code and NIC values conforms to the definition contained in Table A-25. If an update has not been received from an on-board data source for the determination of the TYPE Code value based on the radius of containment within the past 5 seconds, then the TYPE Code value will be encoded to indicate that R_C is “Unknown.”

Table A-25: Navigation Integrity Category (NIC) Encoding.

NIC Value	Radius of Containment (R_C)	Airborne			Surface		
		Airborne Position TYPE Code	NIC Supplement Codes		Surface Position TYPE Code	NIC Supplement Codes	
			A	B		A	C
0	R_C unknown	0, 18 or 22	0	0	0, 8	0	0
1	R_C < 20 NM (37.04 km)	17	0	0	N/A	N/A	N/A
2	R_C < 8 NM (14.816 km)	16	0	0	N/A	N/A	N/A
3	R_C < 4 NM (7.408 km)	16	1	1	N/A	N/A	N/A
4	R_C < 2 NM (3.704 km)	15	0	0	N/A	N/A	N/A
5	R_C < 1 NM (1852 m)	14	0	0	N/A	N/A	N/A
6	R_C < 0.6 NM (1111.2 m)	13	1	1	8	0	1
	R_C < 0.5 NM (926 m)	13	0	0	N/A	N/A	N/A
	R_C < 0.3 NM (555.6 m)	13	0	1	8	1	0
7	R_C < 0.2 NM (370.4 m)	12	0	0	8	1	1
8	R_C < 0.1 NM (185.2 m)	11	0	0	7	0	0
9	R_C < 75m	11	1	1	7	1	0
10	R_C < 25m	10 or 21	0	0	6	0	0
11	R_C < 7.5m	9 or 20	0	0	5	0	0
12	Reserved						
13	Reserved						
14	Reserved						
15	Reserved						

Notes:

1. *"N/A" means "This NIC value is not available in the ADS-B Surface Position Message formats."*

2. *NIC Supplement-A is broadcast in the Aircraft Operational Status Message, "ME" bit 44 (Message bit 76, see Figure A-10). NIC Supplement-B is broadcast in the Airborne Position Message, "ME" bit 8 (Message bit 40, see Figure A-1). NIC Supplement-C is broadcast in the Surface Capability Class (CC) Code Subfield of the Aircraft Operational Status Message, "ME" bit 20 (Message bit 52, see Table A-22).*

A.1.4.10.7 Navigation Accuracy Category for Position (NAC_P)

This 4-bit (ME bits 45 – 48, Message bits 77 – 80) subfield will be used to announce 95% accuracy limits for the horizontal position (and for some NAC_P values, the vertical position) that is being currently broadcast in Airborne Position and Surface Position Messages. Encoding of the subfield will be as shown in Table A-15. If an update has not been received from an on-board data source for NAC_P within the past 5 seconds, then the NAC_P subfield will be encoded as a value indicating "Unknown Accuracy."

A.1.4.10.8 Geometric Vertical Accuracy (GVA)

This 2-bit (ME bits 49 – 50, Message bits 81 – 82) subfield in the Airborne Operational Status Message (Subtype=0) will be encoded as shown in Table A.1.4.10.8, and set by using the Vertical Figure of Merit (VFOM) (95%) from the GNSS position source used to encode the geometric altitude field in the Airborne Position Message.

Table A.1.4.10.8: Encoding of the Geometric Vertical Accuracy (GVA) Subfield in Aircraft Operational Status Messages

GVA Encoding (decimal)	**Meaning** (meters)
0	Unknown or > 45 meters
1	≤ 45 meters
2	Reserved
3	Reserved

Note: *For the purposes of these MOPS (RTCA DO-260B) values for 0 and 1 are encoded. Decoding values for 2 and 3 should be treated as < 45 meters until future versions of these MOPS redefine the values.*

A.1.4.10.9 Source Integrity Level (SIL)

This 2-bit (ME bits 51 – 52, Message bits 83 – 84) subfield is defined for the Target State and Status Message in §A.1.4.9.11 and Table A-17, and remains the same in the Operational Status Message.

A.1.4.10.10 Barometric Altitude Integrity Code (NIC_{BARO})

This 1-bit (ME bit 53, Message bit 85) subfield will be used to indicate whether or not the barometric pressure altitude being reported in the Airborne Position Message (§A.1.4.2) has been cross-checked against another source of pressure altitude. The NIC_{BARO} subfield will be encoded as shown in Table A-16. If an update has not been received from an on-board data source for NIC_{BARO} within the past 5 seconds, then the NIC_{BARO} subfield will be encoded as a value of ZERO (0).

A.1.4.10.11 Aircraft Length and Width Codes

This 4-bit (ME bits 21 – 24, Message bits 53 – 56) subfield will be used in the Surface Aircraft Operational Status Message (Subtype=1) to describe the amount of space that an Aircraft or Ground Vehicle occupies. The A/V Length and Width Code will be based on the actual dimensions of the transmitting Aircraft or Surface Vehicle as specified in Table A-26. Once the actual Length and Width of the A/V has been determined, each A/V will be assigned the smallest A/V Length and Width Code from Table A-26 for which the actual length is less than or equal to the upper bound length for that Length/Width Code, and for which the actual width is less than or equal to the upper bound width for that Length/Width Code.

Table A-26: A/V Length and Width Code

A/V - L/W Code (Decimal)	Length Code			Width Code	Upper-Bound Length and Width for Each Length/Width Code	
	ME Bit 49	ME Bit 50	ME Bit 51	ME Bit 52	Length (meters)	Width (meters)
0	0	0	0	0	No Data or Unknown	
1	0	0	0	1	15	23
2	0	0	1	0	25	28.5
3				1		34
4	0	1	0	0	35	33
5				1		38
6	0	1	1	0	45	39.5
7				1		45
8	1	0	0	0	55	45
9				1		52
10	1	0	1	0	65	59.5
11				1		67
12	1	1	0	0	75	72.5
13				1		80
14	1	1	1	0	85	80
15				1		90

If the Aircraft or Vehicle is longer than 85 meters, or wider than 90 meters, then decimal Aircraft/Vehicle Length/Width Code 15 will be used.

Note: *For example, consider a powered glider with overall length of 24 m and wingspan of 50 m. Normally, an aircraft of that length would be in length category 1 (that is, have a length code of 1). But since the wingspan exceeds 34 m, it does not qualify for even the "wide" subcategory (width code = 1) of length category 1. Such an aircraft would be assigned length code = 4 and width code = 1, meaning "length less than 55 m and width less than 52 m."*

A.1.4.10.12 Track Angle/Heading

The Track Angle/Heading is a 1-bit ("ME" bit 53, Message bit 85) subfield of the ADS-B Aircraft Operational Status Message (Subtype=1, for Surface Participants) that allows correct interpretation of the data contained in the Heading/Ground Track subfield of the ADS-B Surface Position Message when the Air/Ground status is determined to be in the "On-Ground" state as defined in §2.2.3.2.1.2.

A.1.4.10.13 Horizontal Reference Direction (HRD)

This 1-bit (ME bit 54, Message bit 86) subfield will be used to indicate the reference direction (true north or magnetic north) for horizontal directions such as Heading, Track Angle. The Horizontal Reference Direction subfield will be encoded as specified in Table A-27.

Table A-27: Horizontal Reference Direction (HRD) Encoding.

HRD Value	Meaning
0	True North
1	Magnetic North

A.1.4.10.14 System Design Assurance (SDA)

The “System Design Assurance” (SDA) subfield is a 2-bit (“ME” bits 31 – 32, Message bits 63 – 64) field that will define the failure condition that the ADS-B system is designed to support as defined in Table A.1.4.10.14.

The supported failure condition will indicate the probability of an ADS-B system fault causing false or misleading information to be transmitted. The definitions and probabilities associated with the supported failure effect are defined in AC 25.1309-1A, AC 23-1309-1C, and AC 29-2C. All relevant systems attributes should be considered including software and complex hardware in accordance with RTCA DO-178B (EUROCAE ED-12B) or RTCA DO-254 (EUROCAE ED-80).

The ADS-B system includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data transmitted by the ADS-B system.

Table A.1.4.10.14: “System Design Assurance” OM Subfield in Aircraft Operational Status Messages

SDA Value		Supported Failure Condition Note 2	Probability of Undetected Fault causing transmission of False or Misleading Information Note 3,4	Software & Hardware Design Assurance Level Note 1,3
(decimal)	(binary)			
0	00	Unknown/ No safety effect	> $1X10^{-3}$ per flight hour or Unknown	N/A
1	01	Minor	≤ $1X10^{-3}$ per flight hour	D
2	10	Major	≤ $1X10^{-5}$ per flight hour	C
3	11	Hazardous	≤ $1X10^{-7}$ per flight hour	B

Notes:

1. *Software Design Assurance per RTCA DO-178B (EUROCAE ED-12B). Airborne Electronic Hardware Design Assurance per RTCA DO-254 (EUROCAE ED-80).*
2. *Supported Failure Classification defined in AC-23.1309-1C, AC-25.1309-1A, and AC 29-2C.*
3. *Because the broadcast position can be used by any other ADS-B equipped aircraft or by ATC, the provisions in AC 23-1309-1C that allow reduction in failure probabilities and design assurance level for aircraft under 6,000 pounds do not apply.*
4. *Includes probability of transmitting false or misleading latitude, longitude, velocity, or associated accuracy and integrity metrics.*

A.1.4.10.15 SIL Supplement

The "SIL Supplement" (Source Integrity Level Supplement) subfield is a 1-bit ("ME" bit 8, Message bit 40) field that will define whether the reported SIL probability is based on a "per hour" probability or a "per sample" probability as defined in §A.1.4.9.2 and Table A-6.

A.1.4.10.16 TCAS/ACAS Operational

The "TCAS/ACAS Operational" subfield ("ME" bit 11, Message bit 43) of the CC Codes subfield in ADS-B Aircraft Operational Status Messages (TYPE=31, SUBTYPE=0, for airborne participants) is used to indicate whether the TCAS/ACAS System is Operational or not, and remains as defined for use in the Target State and Status Message (§A.1.4.9.18), with the encoding as specified in Table A.1.4.9.18.

A.1.4.10.17 1090ES IN

The CC Code subfield for "1090ES IN" in Aircraft Operational Status Messages (TYPE=31, Subtype=0 or 1) is a 1-bit field ("ME" bit 12, Message bit 44) that is set to ONE (1) if the transmitting aircraft has the capability to receive ADS-B 1090ES Messages. Otherwise, this CC code subfield is set to ZERO (0).

A.1.4.10.18 UAT IN

The "UAT IN" CC Code subfield ("ME" bit 19, Message bit 51, TYPE=31, Subtype=0, for airborne participants AND "ME" Bit 16, Message bit 48, TYPE=31, Subtype=1 for surface participants) in ADS-B Aircraft Operational Status Messages is so called because it denotes whether the aircraft is equipped with the capability to receive ADS-B Universal Access Transceiver (UAT) Messages.

The "UAT IN" CC Code in Aircraft Operational Status Messages is set to ZERO (0) if the aircraft is NOT fitted with the capability to receive ADS-B UAT Messages. The "UAT IN" CC Code Subfield is set to ONE (1) if the aircraft has the capability to receive ADS-B UAT Messages.

A.1.4.10.19 Navigation Accuracy Category for Velocity (NAC_V)

This 3-bit subfield (ME bits 17-19, Message bits 49-51) indicates the Navigation Accuracy Category for Velocity (NAC_V) as defined in §A.1.4.5.5, with the encoding as specified in Table A-5.

A.1.4.10.20 NIC Supplement-C

The NIC Supplement-C subfield in the Aircraft Operational Status Message is a one-bit subfield ("ME" bit 20, Message bit 52) that, together with the TYPE subfield in Surface Position Messages and the NIC Supplement-A in the Operational Status Message ("ME"

Bit 44, Message Bit 76), is used to encode the Navigation Integrity Category (NIC) of the transmitting ADS-B participant.

If an update has not been received from an on-board data source for the determination of the NIC value within the past 5 seconds, then the NIC Supplement subfield is encoded to indicate the larger Radius of Containment (R_C).

Table A-25 lists the possible NIC codes and the values of the TYPE subfield of the Airborne and Surface Position Messages, and of the NIC Supplement subfields that are used to encode those NIC codes in messages on the 1090 MHz ADS-B data link.

A.1.4.10.21 GPS Antenna Offset

The "GPS Antenna Offset" subfield is an 8-bit ("ME" bits 33 – 40, Message bits 65 – 72) field in the OM Code Subfield of surface format Aircraft Operational Status Messages that defines the position of the GPS antenna in accordance with the following, when the Position Offset Applied (see Table A-22) is set to ZERO (0).

a. Lateral Axis GPS Antenna Offset:

"ME" bits 33 through 35 (Message bits 65 through 67) are used to encode the lateral distance of the GPS Antenna from the longitudinal axis (Roll) axis of the aircraft. Encoding is established in accordance with Table A.1.4.10.21A.

Table A.1.4.10.21A: Lateral Axis GPS Antenna Offset Encoding

"ME" Bit (Message Bit)			**GPS Antenna Offset Along Lateral (Pitch) Axis Left or Right of Longitudinal (Roll) Axis**	
33 (65)	**34** (66)	**35** (67)		
0 = left 1 = right	**Encoding**			
	Bit 1	**Bit 0**	**Direction**	**(meters)**
0	0	0	**LEFT**	0 ***or*** **NO DATA**
	0	1		2
	1	0		4
	1	1		6
1	0	0	**RIGHT**	0 ***or*** **NO DATA**
	0	1		2
	1	0		4
	1	1		6

Notes:

1. *Left means toward the left wing tip moving from the longitudinal center line of the aircraft.*
2. *Right means toward the right wing tip moving from the longitudinal center line of the aircraft.*
3. *Maximum distance left or right of aircraft longitudinal (roll) axis is 6 meters or 19.685 feet.*

b. Longitudinal Axis GPS Antenna Offset:

"ME" bits 36 through 40 (Message bits 68 through 72) are used to encode the longitudinal distance of the GPS Antenna from the NOSE of the aircraft. Encoding is established in accordance with Table A.1.4.10.21B.

Table A.1.4.10.21B: Longitudinal Axis GPS Antenna Offset Encoding

"ME" Bit (Message Bit)					**GPS Antenna Offset Along Longitudinal (Roll) Axis Aft From Aircraft Nose**
36 (68)	**37** (69)	**38** (70)	**39** (71)	**40** (72)	
Encoding					
Bit 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**(meters)**
0	0	0	0	0	0 ***or*** **NO DATA**
0	0	0	0	1	2
0	0	0	1	0	4
0	0	0	1	1	6
0	0	1	0	0	8
*	*	*	*	*	***
*	*	*	*	*	***
*	*	*	*	*	***
1	1	1	1	1	62
Note: *Maximum distance aft from aircraft nose is 62 meters or 203.412 feet.*					

When Position Offset Applied (see Table A-22) is set to ONE (1), the GPS Antenna Offset subfield is set to ALL ZEROs (0).

Note: *When Position Offset Applied (see Table A-22) is set to ONE (1), it means that the GPS antenna position has already been compensated for in the reported latitude and longitude position subfields of the Surface Position Message. Ensuring that the GPS Antenna subfield is set to ALL ZEROs in this case ensures that the offset compensation is not performed again by a receiving application.*

A.1.5 Initialization and Timeout

Note: *Initialization and timeout functions for Extended Squitter broadcast are performed by the transponder and are specified in RTCA/DO-181D. A description of these functions is presented in the following paragraphs to serve as reference material for the section on the GFM (§A.1.6).*

A.1.5.1 Initiation of Extended Squitter Broadcast

At power up initialization, the transponder will commence operation in a mode in which it broadcasts only acquisition squitters. The transponder will initiate the broadcast of Extended Squitters for Airborne Position, Surface Position, Aircraft Identification and Category, Airborne Velocity, Target State and Status and Operational Status when data are inserted into Registers 05_{16}, 06_{16}, 08_{16}, 09_{16}, 62_{16} and 65_{16} respectively. This determination will be made individually for each squitter type. The insertion of just altitude or surveillance status data into Register 05_{16} by the transponder will not satisfy the minimum requirement for broadcast of the airborne position squitter.

Note: *This suppresses the transmission of Extended Squitters from aircraft that are unable to report position, velocity or identity information.*

A.1.5.2 Register Timeout

Notes:

1. *These Registers are cleared to prevent the reporting of outdated position and velocity information.*

2. *During a register timeout event, the "ME" field of the ADS-B Broadcast Message may contain ALL ZEROs, except for those fields that may be updated due to the receipt of new data.*

a. The ADS-B Transmitting Subsystem will clear all but the altitude and surveillance status subfields of the Airborne Position Message, if no new position data is received within two (2) seconds of the previous input data update.

   Note: *During a timeout event the Format TYPE Code is set to ZERO (see §2.2.3.2.3.1.3.1).*

b. The ADS-B Transmitting Subsystem will clear all 56-bits of the Surface Position Message if no new position data is received within two (2) seconds of the previous input data update.

   Notes:

   1. *During a timeout event the Format TYPE Code is set to ZERO (see §2.2.3.2.4.1.3.1).*

   2. *When position is available, the ADS-B Transmitting Subsystem manages the movement and the ground track subfields such that the subfields and applicable status bits are set to ZERO (0) if no new data is received for the subfield within 2.6 seconds of the last data update of the subfield.*

   3. *When position data is not received, all bits of the Surface Position Message are set to ZERO to avoid confusion with altitude data in the Airborne Position Message sent with TYPE Code ZERO (0).*

c. The ADS-B Transmitting Subsystem will clear all 56-bits of the Airborne Velocity Message if no data is received within 2.6 seconds of the previous input data update.

Note: *The Intent Change information is not sufficient to consider that new data has been received (§2.2.3.2.6.1.3).*

d. The ADS-B Transmitting Subsystem will not clear the Aircraft Identification Message (see §2.2.3.2.5).

Note: *The Aircraft Identification Message, is not cleared since it contains data that rarely changes in flight and is not frequently updated.*

e. The ADS-B Transmitting Subsystem will clear each of the Selected Altitude, Selected Heading, or Barometric Pressure Setting subfields of the Target State and Status Message (see §2.2.3.2.7.1) if no new data is received within 2.0 seconds of the previous input data update for the respective subfield. Each of the subfields will be cleared independently of the other subfields. That is, each of the three specified subfields will be processed mutually exclusively of the other two specified subfields. The remaining subfields of the Target State and Status Message will not be cleared, as they contain other integrity, mode, or status information.

f. The ADS-B Transmitting Subsystem will not clear the Operational Status Messages (see §2.2.3.2.7.2) since the subfields of the Message contain various integrity, mode, or status information..

g. The ADS-B Transmitting Subsystem will not clear the Event-Driven Messages (see §2.2.3.2.7.8).

Note: *The Event-Driven Messages do not need to be cleared since contents of such messages are only broadcast once each time that new data is received.*

A.1.5.3 Termination of Extended Squitter Broadcast

If input to Register 05_{16}, or 06_{16} stops for 60 seconds, broadcast of the associated Extended Squitter type will be discontinued until data insertion is resumed. The insertion of altitude by the transponder will satisfy the minimum requirement for continuing to broadcast the airborne position squitter.

If input to Register 0916 stops for 2.6 seconds, broadcast of the associated Extended Squitter type will be discontinued until data insertion is resumed.

Notes:

1. *Until timeout, an Extended Squitter type may contain an ME field of ALL ZEROs.*

2. *Continued transmission for 60 seconds is required so that receiving aircraft will know that the data source for the message has been lost.*

A.1.5.4 Requirements for Non-Transponder Devices

Non-Transponder Devices will provide the same functionality for initialization, Register timeout and broadcast termination as specified for the transponder case in §A.1.5.1 through §A.1.5.3.

1. A Non-Transponder Device will not broadcast acquisition squitters, and

2. A Non-Transponder Device operating on the surface will continue to broadcast DF=18 Messages with the TYPE Code=0 at a rate specified for the Surface Position Message, even though it has lost its navigation input.

   Note: *Continued broadcast of the Surface Position Message is needed to support the operation of surface multi-lateration systems.*

A.1.6 General Formatter/Manager (GFM)

Note: *The General Formatter/Manager (GFM) is the name that will be used to refer to the function that formats messages for insertion in the Extended Squitter registers. In addition to data formatting, there are other tasks that have to be performed by this function.*

A.1.6.1 Navigation Source Selection

The GFM will be responsible for the selection of the default source for aircraft position and velocity, the commanded altitude source, and for the reporting of the associated position and altitude errors.

A.1.6.2 Loss of Input Data

The GFM will be responsible for loading the registers for which it is programmed at the required update rate. If for any reason data is unavailable for a time equal to twice the update interval or 2 seconds (whichever is greater), the GFM will ZERO old data (on a per field basis) and insert the resulting message into the appropriate register.

Note: *For Register 05_{16} and 06_{16} a loss of position data would cause the GFM to set the Format TYPE Code to ZERO as the means of indicating "no position data" since ALL ZEROs in the lat/lon fields is a legal value.*

A.1.6.3 Special Processing for Format TYPE Code Zero

A.1.6.3.1 Significance of Format TYPE Code Equal to Zero

Notes:

1. *Format TYPE Code ZERO (0) is labeled "no position information." This is intended to be used when the lat/lon information is not available or invalid, and still permit the reporting of baro altitude loaded by the transponder. The principal use of this message case is to provide ACAS the ability to passively receive altitude.*

2. *Special handling is required for the airborne and Surface Position Messages because a CPR encoded value of ALL ZEROs in the Lat/Lon field is a valid value.*

A.1.6.3.2 Broadcast of Format TYPE Code Equal to Zero

Format TYPE Code 0 will only be set by the following events:

1. Airborne Position or Surface Position (Register 05_{16}, and 06_{16}) has not been loaded by the GFM for 2 seconds. In this case the transponder clears the entire 56 bits of the register that timed out. (In the case of the Airborne Position register, the altitude subfield is only ZEROed if no altitude data is available). Transmission of the Airborne and Surface Position Extended Squitter that broadcasts the timed out register will itself stop in 60 seconds except for the Airborne Position Message when Altitude is still available. Broadcast of this Extended Squitter will resume when the GFM begins to insert data into the register.

2. The GFM determines that all navigation sources that can be used for the Extended Squitter airborne or Surface Position Message are either missing or invalid. In this case the GFM can clear the Format TYPE Code and all other fields of the airborne position, surface position and insert this zeroed message in the appropriate register. This should only be done once so that the transponder can detect the loss of data insertion and suppress the broadcast of the related squitter.

Note that in all of the above cases, a Format TYPE Code of ZERO contains a message of ALL ZEROs. The only exception is the airborne position format that may contain barometric altitude and surveillance status data as set by the transponder. There is no analogous case for the other Extended Squitter format types, since a ZERO value in any of the fields indicates no information. No other squitter types are broadcast with TYPS Code equal ZERO (0).

A.1.6.3.3 Reception of Format TYPE Code Equal to Zero

If a squitter with format TYPE Code equal to ZERO (0) is received, it will be checked to see if altitude is present. If altitude is not present, the message will be discarded. If altitude is present, it may be used to update altitude. An Extended Squitter containing Format TYPE Code ZERO will only be used to update the altitude of an aircraft already in track.

Note: *For ACAS, this could be an aircraft that was being maintained via hybrid surveillance when the position data input failed. In this case, altitude only could be used for a short period of time. Interrogation would have to begin at the update rate for that track to ensure update of range and bearing information on the display.*

A.1.6.4 Handling of Event-Driven Protocol

The Event-Driven interface protocol will provide a general-purpose interface into the transponder function for either those messages beyond those that are regularly transmitted all the time (provided input data is available), or those that are transmitted at a fixed periodic rate. This protocol will operate by having the transponder broadcast a message once each time the Event-Driven register is loaded by the GFM.

Note: *This gives the GFM complete freedom in setting the update rate (up to a maximum) and duration of broadcast for applications such as emergency status and intent reporting.*

In addition to formatting, the GFM will control the timing of message insertion so that it provides the necessary pseudo-random timing variation and does not exceed the maximum transponder broadcast rate for the Event-Driven protocol.

A.1.6.4.1 Transponder Support for the Event Driven Protocol

A message will be transmitted once by the transponder, each time that Register $0A_{16}$ is loaded. Transmission will be delayed if the transponder is busy at the time of insertion.

Note: *Delay times are short, a maximum of several milliseconds for the longest transponder transaction.*

The maximum transmission rate for the Event-Driven protocol will limited by the transponder to twice per second. If a message is inserted in the Event-Driven register and cannot be transmitted due to rate limiting, it will be held and transmitted when the rate limiting condition has cleared. If a new message is received before transmission is permitted, it will overwrite the earlier message.

Note: *The squitter transmission rate and the duration of squitter transmissions is application dependent. Choices made should be the minimum rate and duration consistent with the needs of the application.*

A.1.6.4.2 GFM Use of the Event-Driven Protocol

Note: *More than one application at a time may be supported by the Event-Driven protocol. The GFM handles requests for broadcast by these applications and is the only function that is capable of inserting data into Register $0A_{16}$. In this way, the GFM can provide the pseudo random timing for all applications using this protocol and maintain a maximum insertion rate that does not exceed the transponder imposed limit.*

An application that wants to use the Event-Driven protocol will notify the GFM of the format type and required update rate. The GFM will then locate the necessary input data for this format type and begin inserting data into Register $0A_{16}$ at the required rate. The GFM will also insert this message into the register for this format type. This register image will be maintained to allow readout of this information by air-ground or air-air register readout. When broadcast of a format type ceases, the GFM will clear the corresponding register assigned to this message.

The maximum rate that can be supported by the Event-Driven protocol will be twice per second from one or a collection of applications. For each Event-Driven format type being broadcast, the GFM will retain the time of the last insertion into Register $0A_{16}$. The next insertion will be scheduled at a random interval that is uniformly distributed over the range of the update interval ±0.1 second relative to the previous insertion into Register $0A_{16}$ for this format type.

The GFM will monitor the number of insertions scheduled in any one second interval. If more than two would occur, the GFM will schedule the pending messages based on message priorities and queue management rules defined in §A.1.4.6.3 in order to ensure that the limit of two messages per second is observed while ensuring that high priority Extended Squitter Message as broadcast at the required rates.

A.1.6.4.3 Event-Driven Message Transmission Scheduling Function

The Event-Driven Message Scheduling Function will ensure that the total Event-Driven Message rate does not exceed 2 transmitted messages per second.

The Event-Driven Message Scheduling Function will apply the following rules as a means of prioritizing the Event-Driven Message transmissions and limited the transmission rates:

a. The Event-Driven Message scheduling function will reorder, as necessary, pending Event-Driven Messages according to the following message priorities, listed below in descending order from highest to lowest priority:

   i. When an Extended Squitter Status Message is active for the broadcast of an Emergency/Priority Condition (TYPE=28 and Subtype=1), or a TCAS RA Broadcast (TYPE=28, Subtype=2), then that message will continue to be transmitted at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds, relative to the previous respective Aircraft Status Message for the duration of the emergency or TCAS RA condition if the Target State and Status Message is not being broadcast. If the "Target State and Status Message" with Subtype=0 is being broadcast, then the "Emergency/Priority Status," or the TCAS RA Broadcast Message will be broadcast at random intervals that are uniformly distributed over the range of 2.4 to 2.6 seconds relative to the previous respective Aircraft Status Message for the duration of the emergency condition established in accordance with Figure A-8, Note 2, or TCAS RA (established in accordance with the notes in Figure A-8b). The broadcast of the 1090ES ADS-B Aircraft Status TCAS RA Broadcast Message takes priority over the Emergency/Priority Status broadcast, and all other Event-Driven Message types.

   ii. Reserved for future use.

   iii. Reserved for future use.

   iv. When an Aircraft Operational Status Message is active (TYPE=31 and Subtype=0) and there has been a change in one or more of the message parameters within the past 24 seconds that results in a higher update rate reporting requirement, the Aircraft Operational Status Message will be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds. When enabled, the "TEST" Message with Subtype=7 **shall** be broadcast at random intervals that are uniformly distributed over the range of 11.8 to 12.2 seconds from the time of transmission of the previous "TEST" Message with Subtype=7.

   v. When a Target State and Status Message is active for the broadcast of Target State information (message TYPE=29 and Subtype=0) the Target State and Status Message will be transmitted at random intervals that are uniformly distributed over the range of 1.2 to 1.3 seconds relative to the previous Target State and Status Message for as long as target state information is available and valid.

   vi. Reserved for future use.

vii. When an Aircraft Operational Status Message is active (TYPE=31 and Subtype=0) and there has been no change in the message parameters that would require an increased broadcast rate, the Aircraft Operational Status Message will be broadcast at random intervals uniformly distributed over the range of 2.4 to 2.6 seconds.

viii. This priority level applies as a default to any Event-Driven Message TYPE and Subtype combination not specifically identified at a higher priority level above. Event-Driven Messages of this default priority level will be delivered to the transponder on a first-in-first-out basis at equal priority.

b. The Event-Driven Message scheduling function will limit the number of Event-Driven Messages provided to the transponder to two (2) messages per second.

c. If (b) results in a queue of messages awaiting delivery to the transponder, the higher priority pending messages, according to (a) above will be delivered to the transponder for transmission before lower priority messages.

d. If (b) results in a queue of messages awaiting delivery to the transponder, new Event-Driven messages will directly replace older messages of the same exact Type and Subtype (where a Subtype is defined) that are already in the pending message queue. The updated message will maintain the same position in the message queue as the pending message that is being replaced.

e. If (b) above results in a queue of messages awaiting delivery to the transponder, then pending message(s), will be deleted from the message transmission queue if not delivered to the transponder for transmission, or not replaced with a newer message of the same message Type and Subtype, within the Message Lifetime value specified in the Table A-28 below:

Table A-28: Event-Driven Message Lifetime

Message TYPE	Message Subtype	Message Lifetime (seconds)
23	= 0	5.0 seconds (+/- 0.2 sec.)
	= 1, 2, 3, 4, 5, or 6	Reserved (see Note)
	= 7	24 seconds (+/- 0.2 sec.)
24		Reserved (see Note)
25		Reserved (see Note)
26		Reserved (see Note)
27		Reserved (see Note)
28	= 1	5.0 seconds (+/- 0.2 sec.)
	0, > 1	Reserved (see Note)
29	= 0	2.5 seconds (+/- 0.2 sec.)
	> 0	Reserved (see Note)
30		Reserved (see Note)
31	= 0, 1	5.0 seconds (+/- 0.2 sec.)
	> 1	Reserved (see Note)

Note: *A default message lifetime of 20 seconds will be used for queue management unless otherwise specified.*

A.1.7 Latitude/Longitude Coding Using Compact Position Reporting (CPR)

A.1.7.1 Principle of the CPR algorithm

Notes:

1. *The Mode S Extended Squitters use Compact Position Reporting (CPR) to encode Latitude and Longitude efficiently into messages. The resulting messages are compact in the sense that several higher-order bits, which are normally constant for long periods of time, are not transmitted in every message. For example, in a direct binary representation of latitude, one bit would designate whether the aircraft is in the northern or southern hemisphere. This bit would remain constant for a long time, possibly the entire life of the aircraft. To repeatedly transmit this bit in every position message would be inefficient.*

2. *Because the higher-order bits are not transmitted, it follows that multiple locations on the earth will produce the same encoded position. If only a single position message were received, the decoding would involve ambiguity as to which of the multiple solutions is the correct location of the aircraft. The CPR technique includes a provision to enable a receiving system to unambiguously determine the location of the aircraft. This is done by encoding in two ways that differ slightly. The two formats, called even-format and odd-format, are each transmitted fifty percent of the time. Upon reception of both types within a short period (approximately 10 seconds for airborne formats and 50 seconds for surface formats), the receiving system can unambiguously determine the location of the aircraft.*

3. *Once this process has been carried out, the higher-order bits are known at the receiving station, so subsequent single message receptions serve to unambiguously indicate the location of the aircraft as it moves.*

4. *In certain special cases, a single reception can be decoded into the correct location without an even/odd pair. This decoding is based on the fact that the multiple locations are spaced by at least 360 NM. In addition to the correct locations, the other locations are separated by integer multiples of 360 NM to the north and south and also integer multiples of 360 NM to the east and west. In a special case in which it is known that reception is impossible beyond a range of 180 NM, the nearest solution is the correct location of the aircraft.*

5. *The parameter values in the preceding paragraph (360 and 180 NM) apply to the airborne CPR encoding. For aircraft on the surface, the CPR parameters are smaller by a factor of 4. This encoding yields better resolution but reduces the spacing of the multiple solutions.*

A.1.7.2 CPR Algorithm Parameters and Internal Functions

The CPR algorithm **shall** utilize the following parameters whose values are set as follows for the Mode S Extended Squitter application:

1. The number of bits used to encode a position coordinate, *Nb*, is set as follows:

For airborne encoding, used in the ADS-B Airborne Position Message and the TIS-B Fine Airborne Position Message:	*Nb* = 17
For surface encoding, used in the ADS-B Surface Position Message and the TIS-B Fine Surface Position Message:	*Nb* = 19
For intent encoding:	*Nb* = 14
For TIS-B encoding, used only in the TIS-B Coarse Airborne Position Message:	*Nb* = 12

Note 1: *The Nb parameter determines the encoded position precision (approximately 5 m for the airborne encoding, 1.25 m for the surface encoding, 41 m for the intent encoding and 164 m for the TIS-B encoding).*

2. The number of geographic latitude zones between the equator and a pole, denoted *NZ*, is set to 15.

Note 2: *The NZ parameter determines the unambiguous airborne range for decoding (360 NM). The surface Latitude/Longitude encoding omits the high-order 2 bits of the 19-bit CPR encoding, so the effective unambiguous range for surface position reports is 90 NM.*

The CPR algorithm **shall** define internal functions to be used in the encoding and decoding processes.

a. The notation **floor**(x) denotes the floor of *x*, which is defined as the greatest integer value *k* such that $k \leq x$.

Note 3: *For example,* ***floor****(3.8) = 3, while* ***floor****(-3.8) = -4.*

b. The notation |*x*| denotes the absolute value of *x*, which is defined as the value *x* when $x \geq 0$ and the value $-x$ when $x < 0$.

c. The notation **MOD**(*x*,*y*) denotes the "modulus" function, which is defined to return the value

$$\text{MOD}(x, y) = x - y \cdot \text{floor}\left(\frac{x}{y}\right) \text{ where } y \neq 0 .$$

Note 4: *The value y is always positive in the following CPR algorithms. When x is non-negative,* ***MOD****(x,y) is equivalent to the remainder of x divided by y. When x represents a negative angle, an alternative way to calculate* ***MOD****(x,y) is to return the remainder of (x+360°) divided by y.*

For example, $\text{MOD}(-40°,6°) = \text{MOD}(320°,6°) = 2°$.

d. The notation **NL**(*x*) denotes the "number of longitude zones" function of the latitude angle *x*. The value returned by **NL**(*x*) is constrained to the range from 1 to 59. **NL**(*x*) is defined for most latitudes by the equation,

$$\text{NL}(lat) = \text{floor}\left(2\pi \cdot \left[\arccos\left(1 - \frac{1-\cos\left(\frac{\pi}{2 \cdot NZ}\right)}{\cos^2\left(\frac{\pi}{180°} \cdot |lat|\right)}\right)\right]^{-1}\right),$$

where *lat* denotes the latitude argument in degrees. For latitudes at or near the N or S pole, or the equator, the following points are defined:

For *lat* = 0 (the equator), NL = 59

For *lat* = +87 degrees, NL = 2

For *lat* = -87 degrees, NL = 2

For *lat* > +87 degrees, NL = 1

For *lat* < -87 degrees, NL = 1

Note 5: *This equation for NL() is impractical for a real-time implementation. A table of transition latitudes can be pre-computed using the following equation:*

$$lat = \frac{180°}{\pi} \cdot \arccos\left(\sqrt{\frac{1-\cos\left(\frac{\pi}{2 \cdot NZ}\right)}{1-\cos\left(\frac{2\pi}{NL}\right)}}\right) \text{ for } NL = 2 \text{ to } 4 \cdot NZ - 1,$$

and a table search procedure used to obtain the return value for NL( ). *The table value for NL = 1 is 90 degrees. When using the look up table established by using the equation above, the NL value is not expected to change to the next lower NL value until the boundary (latitude established by the above equation) has actually been crossed when moving from the equator towards the pole.*

A.1.7.3 CPR Encoding Process

The CPR encoding process **shall** calculate the encoded position values XZ_i and YZ_i for either airborne, surface, intent, or TIS-B Latitude and Longitude fields from the global position *lat* (latitude in degrees), *lon* (longitude in degrees), and the CPR encoding type *i* (0 for even format and 1 for odd format), by performing the following sequence of computations. The CPR encoding for intent always uses the even format (*i* = 0), whereas the airborne, surface, and TIS-B encoding use both even (*i* = 0) and odd (*i* = 1) formats.

a. $Dlat_i$ (the latitude zone size in the N-S direction) is computed from the equation:

$$Dlat_i = \frac{360^\circ}{4 \cdot NZ - i}$$

b. YZ_i (the Y-coordinate within the Zone) is then computed from $Dlat_i$ and lat using separate equations:

For *N*b = 17: $$YZ_i = \text{floor}\left(2^{17} \cdot \frac{\text{MOD}(lat, Dlat_i)}{Dlat_i} + \frac{1}{2}\right)$$

For *Nb* = 19: $$YZ_i = \text{floor}\left(2^{19} \cdot \frac{\text{MOD}(lat, Dlat_i)}{Dlat_i} + \frac{1}{2}\right)$$

For *Nb* = 14: $$YZ_0 = \text{floor}\left(2^{14} \cdot \frac{\text{MOD}(lat, Dlat_0)}{Dlat_0} + \frac{1}{2}\right)$$

For *Nb* = 12: $$YZ_i = \text{floor}\left(2^{12} \cdot \frac{\text{MOD}(lat, Dlat_i)}{Dlat_i} + \frac{1}{2}\right)$$

c. $Rlat_i$ (the latitude that a receiving ADS-B system will extract from the transmitted message) is then computed from lat, YZ_i, and $Dlat_i$ using separate equations:

For *Nb* = 17: $$Rlat_i = Dlat_i \cdot \left(\frac{YZ_i}{2^{17}} + \text{floor}\left(\frac{lat}{Dlat_i}\right)\right)$$

For *Nb* = 19: $$Rlat_i = Dlat_i \cdot \left(\frac{YZ_i}{2^{19}} + \text{floor}\left(\frac{lat}{Dlat_i}\right)\right)$$

For *Nb* = 14: $$Rlat_0 = Dlat_0 \cdot \left(\frac{YZ_0}{2^{14}} + \text{floor}\left(\frac{lat}{Dlat_0}\right)\right)$$

For *Nb* = 12 $$Rlat_i = Dlat_i \cdot \left(\frac{YZ_i}{2^{12}} + \text{floor}\left(\frac{lat}{Dlat_i}\right)\right)$$

d. $Dlon_i$ (the longitude zone size in the E-W direction) is then computed from $Rlat_i$ using the equation:

$$Dlon_i = \begin{cases} \dfrac{360^\circ}{\text{NL}(Rlat_i) - i}, & \text{when } \text{NL}(Rlat_i) - i > 0 \\ 360^\circ, & \text{when } \text{NL}(Rlat_i) - i = 0 \end{cases}$$

Note: *When performing the NL function, the encoding process must ensure that the NL value is established in accordance with Note 5 of §A.1.7.2.d.*

e. XZ_i (the X-coordinate within the Zone) is then computed from *lon* and $Dlon_i$ using separate equations:

For *Nb* = 17: $$XZ_i = \text{floor}\left(2^{17} \cdot \frac{\text{MOD}(lon, Dlon_i)}{Dlon_i} + \frac{1}{2}\right)$$

For *Nb* = 19: $$XZ_i = \text{floor}\left(2^{19} \cdot \frac{\text{MOD}(lon, Dlon_i)}{Dlon_i} + \frac{1}{2}\right)$$

For *Nb* = 14: $$XZ_0 = \text{floor}\left(2^{14} \cdot \frac{\text{MOD}(lon, Dlon_0)}{Dlon_0} + \frac{1}{2}\right)$$

For *Nb* = 12: $$XZ_i = \text{floor}\left(2^{12} \cdot \frac{\text{MOD}(lon, Dlon_i)}{Dlon_i} + \frac{1}{2}\right)$$

f. Finally, limit the values of XZ_i and YZ_i to fit in the 17-bit, 14-bit or 12-bit field allotted to each coordinate:

For *Nb* = 17: $$YZ_i = \text{MOD}(YZ_i, 2^{17}),$$ $$XZ_i = \text{MOD}(XZ_i, 2^{17})$$

For *Nb* = 19: $$YZ_i = \text{MOD}(YZ_i, 2^{17}),$$ $$XZ_i = \text{MOD}(XZ_i, 2^{17})$$

For *Nb* = 14: $$YZ_0 = \text{MOD}(YZ_0, 2^{14}),$$ $$XZ_0 = \text{MOD}(XZ_0, 2^{14})$$

For *Nb* = 12: $$YZ_i = \text{MOD}(YZ_i, 2^{12}),$$ $$XZ_i = \text{MOD}(XZ_i, 2^{12})$$

A.1.7.4 Locally Unambiguous CPR Decoding

The CPR algorithm **shall** decode a geographic position (latitude, $Rlat_i$, and longitude, $Rlon_i$,) that is locally unambiguous with respect to a reference point (lat_s, lon_s) known to be within 180 NM of the true airborne position (or within 45 NM for a surface message).

Note: *This reference point may be a previously tracked position that has been confirmed by global decoding (§A.1.7.7) or it may be the own aircraft position, which would be used for decoding a new tentative position report.*

The encoded position coordinates XZ_i and YZ_i and the CPR encoding type *i* (0 for the even encoding and 1 for the odd encoding) contained in a Mode S Extended Squitter message **shall** be decoded by performing the sequence of computations given in §A.1.7.5 for the airborne and intent format types and in §A.1.7.6 for the surface format type.

A.1.7.5 Locally Unambiguous CPR Decoding for Airborne, TIS-B and Intent Lat/Lon

The following computations **shall** be performed to obtain the decoded lat/lon for the airborne, intent, and TIS-B messages. For intent lat/lon, i is always 0 (even encoding), whereas airborne and TIS-B lat/lon use both even (i=0) and odd (i=1) encodings. For airborne lat/lon, Nb=17, for intent, Nb=14, and for TIS-B Nb=12

a. $Dlat_i$ is computed from the equation:

$$Dlat_i = \frac{360°}{4 \cdot NZ - i}$$

b. The latitude zone index number, j, is then computed from the values of lat_s, $Dlat_i$ and YZ_i using the equation:

$$j = \text{floor}\left(\frac{lat_s}{Dlat_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lat_s, Dlat_i)}{Dlat_i} - \frac{YZ_i}{2^{Nb}}\right)$$

c. The decoded position latitude, $Rlat_i$, is then computed from the values of j, $Dlat_i$, and YZ_i using the equation:

$$Rlat_i = Dlat_i \cdot \left(j + \frac{YZ_i}{2^{Nb}}\right)$$

d. $Dlon_i$ (the longitude zone size in the E-W direction) is then computed from $Rlat_i$ using the equation:

$$Dlon_i = \begin{cases} \dfrac{360°}{\text{NL}(Rlat_i) - i}, & \text{when NL}(Rlat_i) - i > 0 \\ 360°, & \text{when NL}(Rlat_i) - i = 0 \end{cases}$$

Note: *When performing the NL function, the encoding process must ensure that the NL value is established in accordance with Note 5 of §A.1.7.2.d.*

e. The longitude zone coordinate m is then computed from the values of lon_s, $Dlon_i$, and XZ_i using the equation:

$$m = \text{floor}\left(\frac{lon_s}{Dlon_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lon_s, Dlon_i)}{Dlon_i} - \frac{XZ_i}{2^{Nb}}\right)$$

f. The decoded position longitude, $Rlon_i$, is then computed from the values of m, XZ_i, and $Dlon_i$ using the equation:

$$Rlon_i = Dlon_i \cdot \left(m + \frac{XZ_i}{2^{Nb}}\right)$$

A.1.7.6 Locally Unambiguous Decoding for Surface Position

The following computations **shall** be performed to obtain the decoded Latitude and Longitude for the surface position format.

1. $Dlat_i$ is computed from the equation:

$$Dlat_i = \frac{90°}{4 \cdot NZ - i}$$

2. The latitude zone index, j, is then computed from the values of lat_s, $Dlat_i$ and YZ_i using the equation:

$$j = \text{floor}\left(\frac{lat_s}{Dlat_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lat_s, Dlat_i)}{Dlat_i} - \frac{YZ_i}{2^{17}}\right)$$

3. The decoded position latitude, $Rlat_i$, is then computed from the values of j, $Dlat_i$, and YZ_i using the equation:

$$Rlat_i = Dlat_i \cdot \left(j + \frac{YZ_i}{2^{17}}\right)$$

4. $Dlon_i$ (the longitude zone size, in the E-W direction) is then computed from $Rlat_i$ using the equation:

$$Dlon_i = \begin{cases} \dfrac{90°}{\text{NL}(Rlat_i) - i}, & \text{when NL}(Rlat_i) - i > 0 \\ 90°, & \text{when NL}(Rlat_i) - i = 0 \end{cases}$$

Note: *When performing the NL function, the encoding process must ensure that the NL value is established in accordance with Note 5 of §A.1.7.2.d.*

5. The longitude zone coordinate m is then computed from the values of lon_s, $Dlon_i$, and XZ_i using the equation:

$$m = \text{floor}\left(\frac{lon_s}{Dlon_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lon_s, Dlon_i)}{Dlon_i} - \frac{XZ_i}{2^{17}}\right)$$

6. The decoded position longitude, $Rlon_i$, is then computed from the values of m, XZ_i, and $Dlon_i$ using the equation:

$$Rlon_i = Dlon_i \cdot \left(m + \frac{XZ_i}{2^{17}}\right)$$

A.1.7.7 Globally Unambiguous Airborne Position Decoding

The CPR algorithm **shall** utilize one airborne-encoded "**even**" format reception (denoted XZ_0, YZ_0), together with one airborne-encoded "**odd**" format reception (denoted XZ_1, YZ_1), to regenerate the global geographic position latitude, *Rlat*, and longitude, *Rlon*. The time between the "**even**" and "**odd**" format encoded position reports **shall** be not longer than 10 seconds for airborne formats.

Note 1: *This algorithm might be used to obtain globally unambiguous position reports for aircraft out of the range of ground sensors, whose position reports are coming via satellite data links. It might also be applied to ensure that local positions are being correctly decoded over long ranges from the receiving sensor.*

Note 2: *The time difference limit of 10 seconds between the even- and odd-format position reports for airborne formats is determined by the maximum permitted separation of 3 NM. Positions greater than 3 NM apart cannot be used to solve for a unique global position. An aircraft capable of a speed of 1,850 km/h (1,000 kt) will fly about 5.1 km (2.8 NM) in 10 seconds. Therefore, the CPR algorithm will be able to unambiguously decode its position over a 10-second delay between position reports.*

Given a 17-bit airborne position encoded in the "**even**" format (XZ_0, YZ_0) and another encoded in the "**odd**" format (XZ_1, YZ_1), separated by no more than 10 seconds (= 3 NM), the CPR algorithm **shall** regenerate the geographic position from the encoded position reports by performing the following sequence of steps:

a. Compute $Dlat_0$ and $Dlat_1$ from the equation:

$$Dlat_i = \frac{360°}{4 \cdot NZ - i}$$

b. Compute the latitude index:

$$j = \text{floor}\left(\frac{59 \cdot YZ_0 - 60 \cdot YZ_1}{2^{17}} + \frac{1}{2}\right)$$

c. Compute the values of $Rlat_0$ and $Rlat_1$ using the following equation:

$$Rlat_i = Dlat_i \cdot \left(\text{MOD}(j, 60 - i) + \frac{YZ_i}{2^{17}}\right)$$

Southern hemisphere values of $Rlat_i$ will fall in the range from 270° to 360°. Subtract 360° from such values, thereby restoring $Rlat_i$ to the range from –90° to +90°.

d. If **NL**($Rlat_0$) is not equal to **NL**($Rlat_1$) then the two positions straddle a transition latitude—thus a solution for global longitude is not possible. Wait for positions where they are equal.

Note 3: *When performing the NL function, the encoding process must ensure that the NL value is established in accordance with Note 5 of §A.1.7.2.d. This is more important in the Global Unambiguous Decode because large longitude errors are induced if the decode function is not selecting the NL value properly as discussed in Note 5 of §A.1.7.2.d.*

e. If **NL**($Rlat_0$) is equal to **NL**($Rlat_1$) then proceed with computation of $Dlon_i$, according to whether the most recently received Airborne Position Message was encoded with the even format (i = 0) or the odd format (i = 1) :

$$Dlon_i = \frac{360°}{n_i},$$

$$\text{where } n_i = \text{greater of } \left[\text{NL}(Rlat_i) - i\right] \text{ and } 1 .$$

f. Compute m, the longitude index:

$$m = \text{floor}\left(\frac{XZ_0 \cdot (NL - 1) - XZ_1 \cdot NL}{2^{17}} + \frac{1}{2}\right),$$

$$\text{where } NL = \text{NL}(Rlat_i).$$

g. Compute the global longitude, $Rlon_0$ or $Rlon_1$, according to whether the most recently received Airborne Position Message was encoded using the even format (that is, with i = 0) or the odd format (i = 1):

$$Rlon_i = Dlon_i \cdot \left(\text{MOD}(m, n_i) + \frac{XZ_i}{2^{17}}\right),$$

$$\text{where } n_i = \text{greater of } \left[\text{NL}(Rlat_i) - i\right] \text{ and } 1 .$$

h. A reasonableness test **shall** be applied to the resulting decoded position in accordance with §A.1.7.10.2.

A.1.7.8 Globally Unambiguous CPR Decoding of Surface Position

This algorithm **shall** utilize one CPR surface position encoded "***even***" format message together with one CPR surface position encoded "***odd***" format message, to regenerate the geographic position of the aircraft or target.

As surface-format messages are initially received from a particular aircraft, if there is no prior history of this aircraft, then a global decode **shall** be performed using "***even***" and "***odd***" format receptions, as described in this section.

Note 1: *If the aircraft has been transmitting airborne format messages and their receptions were in-track, then it is not necessary to use even-odd decoding. Beginning with the first individual Surface Position Message reception, the location can be decoded using the local-decode technique, based on the previous target location as the reference.*

Note 2: *Even if the aircraft is appearing for the first time in surface format receptions, any single message could be decoded by itself into multiple locations, one being the correct location of the transmitting aircraft, and all of the others being separated by 90 NM or more from the correct location. Therefore, if it were known that the transmitting aircraft cannot be farther away than 45 NM from a known location, then the first received message could be decoded using the locally unambiguous decoding method described in §A.1.7.6. Under some circumstances it may be possible for an aircraft to be first detected when it is transmitting Surface Position Messages farther than 45 NM away from the receiving station. For this reason, even-odd decoding is required when messages are initially received from a particular aircraft. After this initial decode, as subsequent messages are received, they can be decoded individually (without using the even-odd technique), provided that the intervening time is not excessive. This subsequent decoding is based on the fact that the aircraft location has not changed by more than 45 NM between each new reception and the previously decoded location.*

The ***even-odd*** decoding process **shall** begin by identifying a pair of receptions, one in the "***even***" format, the other in the "***odd***" format, and whose separation in time does not exceed the time interval of **X** seconds, where **X**=50 seconds, unless the Ground Speed in either Surface Position Message is greater than 25 knots, or is unknown, in which cases **X**=25 seconds.

Note 3: *The limit of 25 seconds is based on the possible change of location within this time interval. Detailed analysis of CPR indicates that if the change of location is 0.75 NM or less, then the decoding will yield the correct location of the aircraft. To assure that the change of location is actually no larger, and considering the maximum aircraft speed of 100 knots specified for the transmission of the surface format, the combination indicates that 25 seconds will provide the needed assurance. For targets on the airport surface when speeds are much less and the transmission rate is as low as one per 5 seconds, the corresponding time limit is 50 seconds.*

Given a CPR 17-bit surface position encoded in the "***even***" format (XZ0, YZ0) and another encoded in the "***odd***" format (XZ1, YZ1), separated by no more than **X** seconds, the algorithm **shall** regenerate the geographic position (latitude *Rlat*, and longitude *Rlon*) of the aircraft or target by performing the following sequence of steps:

a. Compute the latitude zone sizes $Dlat_0$ and $Dlat_1$ from the equation:

$$Dlat_i = \frac{90°}{60 - i}$$

b. Compute the latitude index:

$$j = floor\left(\frac{59 \cdot YZ_o - 60YZ_1}{2^{17}} + \frac{1}{2}\right)$$

c. Latitude. The following formulas will yield two mathematical solutions for latitude (for each value of *i*), one in the northern hemisphere and the other in the southern hemisphere. Compute the northern hemisphere solution of $Rlat_0$ and $Rlat_1$ using the following equation:

$$Rlat_i = Dlat_i\left(MOD(j, 60-i) + \frac{YZ_i}{2^{17}}\right)$$

The southern hemisphere value is the above value minus 90 degrees.

To determine the correct latitude of the target, it is necessary to make use of the location of the receiver. Only one of the two latitude values will be consistent with the known receiver location, and this is the correct latitude of the transmitting aircraft.

d. The first step in longitude decoding is to check that the ***even-odd*** pair of messages do not straddle a transition latitude. It is rare, but possible, that NL($Rlat_0$) is not equal to NL($Rlat_1$). If so, a solution for longitude cannot be calculated. In this event, abandon the decoding of this ***even-odd*** pair, and examine further receptions to identify another pair. Perform the decoding computations up to this point and check that these two NL values are equal. When that is true, proceed with the following decoding steps.

Note: *When performing the NL function, the encoding process must ensure that the NL value is established in accordance with Note 5 of §A.1.7.2.d. This is more important in the Global Unambiguous Decode because large longitude errors are induced if the decode function is not selecting the NL value properly as discussed in Note 5 of §A.1.7.2.d.*

e. Compute the longitude zone size $Dlon_i$, according to whether the most recently received surface position message was encoded with the even format (*i*=0) or the odd format (*i*=1):

$$Dlon_i = \frac{90°}{n_i}$$, where n_i is the greater of [$NL(Rlat_i) - i$] and 1.

f. Compute m, the longitude index:

$$m = floor\left(\frac{XZ_0 \cdot (NL-1) - XZ_1 \cdot NL}{2^{17}} + \frac{1}{2}\right)$$

where $NL = NL(Rlat_i)$

g. Longitude. The following formulas will yield four mathematical solutions for longitude (for each value of *i*), one being the correct longitude of the aircraft, and the other three separated by at least 90 degrees. To determine the correct location of the target, it will be necessary to make use of the location of the receiver. Compute the longitude, $Rlon_0$ or $Rlon_1$, according to whether the most recently received surface position message was encoded using the even format (that is, with *i*=0) or the odd format (*i*=1):

$$Rlon_i = Dlon_i \cdot \left(MOD(m, n_i) + \frac{XZi}{2^{17}} \right)$$

where n_i is the greater of [$NL(Rlat_i) - i$] and 1.

This solution for $Rlon_i$ will be in the range 0° to 90°. The other three solutions are 90°, 180°, and 270° to the east of this first solution.

h. A reasonableness test **shall** be applied to the resulting decoded position in accordance with §A.1.7.10.2.

To then determine the correct longitude of the transmitting aircraft, it is necessary to make use of the known location of the receiver. Only one of the four mathematical solutions will be consistent with the known receiver location, and this is the correct longitude of the transmitting aircraft.

Note: *Near the equator the minimum distance between the multiple longitude solutions is more than 5000 NM, so there is no question as to the correct longitude. For locations away from the equator, the distance between solutions is less, and varies according to the cosine of latitude. For example at 87 degrees latitude, the minimum distance between solutions is 280 NM. This is sufficiently large to provide assurance that the correct aircraft location will always be obtained. Currently no airports exist within 3 degrees of either pole, so the decoding as specified here will yield the correct location of the transmitting aircraft for all existing airports.*

A.1.7.9 CPR Decoding of Received Position Reports

A.1.7.9.1 Overview

Note: *The techniques described in the preceding paragraphs (locally and globally unambiguous decoding) are used together to decode the lat/lon contained in airborne, surface intent and TIS-B position reports. The process begins with globally unambiguous decoding based upon the receipt of an even and an odd encoded position squitter. Once the globally unambiguous position is determined, the emitter centered local decoding technique is used for subsequent decoding based on a single position report, either even or odd encoding.*

A.1.7.9.2 Emitter Centered Local Decoding

In this approach, the most recent position of the emitter **shall** be used as the basis for the local decoding.

Note: *This produces an unambiguous decoding at each update, since the transmitting aircraft cannot move more than 360 NM between position updates.*

A.1.7.10 Reasonableness Test for CPR Decoding of Received Position Messages

A.1.7.10.1 Overview

Note: *Although receptions of Position Messages will normally lead to a successful target position determination, it is necessary to safeguard against Position Messages that would be used to initiate or update a track with an erroneous position. A reasonableness test applied to the computed position resulting from receipt of a Position Message can be used to discard erroneous position updates. Since an erroneous globally unambiguous CPR decode could potentially exist for the life of a track, a reasonableness test and validation of the position protects against such occurrences.*

A.1.7.10.2 Reasonableness Test Applied to Position Determined from Globally Unambiguous Decoding

A reasonableness test **shall** be applied to a position computed using the Globally Unambiguous CPR decoding per §A.1.7.7 for Airborne Participants, or per §A.1.7.8 for Surface Participants. Upon receipt of the "***even***" or "***odd***" encoded Position Message that completes the Globally Unambiguous CPR decode, the receiver **shall** perform a reasonableness test on the position decode by performing the following:

If the receiver position is known, calculate the distance between the decoded position and the receiver position, and verify that the distance is less than the maximum reception range of the receiver. If the validation fails, the receiver **shall** discard the decoded position that the "***even***" and "***odd***" Position Messages used to perform the globally unambiguous CPR decode, and reinitiate the Globally Unambiguous CPR decode process.

A further validation of the Globally Unambiguous CPR decode, passing the above test, **shall** be performed by the computation of a second Globally Unambiguous CPR decode based on reception of a new "***odd***" and an "***even***" Position Message as per §A.1.7.7 for an Airborne Participant, or per §A.1.7.8 for a Surface Participant, both received subsequent to the respective "***odd***" and "***even***" Position Message used in the Globally Unambiguous CPR decode under validation. Upon accomplishing the additional Globally Unambiguous CPR decode, this decoded position and the position from the locally unambiguous CPR decode resulting from the most recently received Position Message **shall** be checked to be identical to within 5 meters for an airborne decode and 1.25 meters for a surface decode.. If the two positions are not identical to within this tolerance, the validation is failed and the initial Globally Unambiguous CPR decode under validation **shall** be discarded and the track **shall** be reinitialized.

Note: *The position obtained from the initial global CPR decode is subsequently updated using local CPR decoding, until an independent "**odd**" and "**even**" Position Message pair has been received. When this occurs, a second global CPR decode is performed. The resulting position is compared to the position update obtained from the local CPR decode using the most recently received Position Message. These two positions should agree since they are computed from the same message.*

A.1.7.10.3 Reasonableness Test Applied to Position Determined from Locally Unambiguous Decoding

A reasonableness test **shall** be applied to a position computed using the Locally Unambiguous CPR decoding per §A.1.7.5 for Airborne, TIS-B or Intent Participants, or per §A.1.7.6 for Surface Participants. Upon receipt of the "***even***" or "***odd***" encoded Position Message that completes the Locally Unambiguous CPR decode, the receiver **shall** perform a reasonableness test on the most recently received position decode by performing the following test:

If the difference between the TOMRs of the previously received Position Message and the most recently received Position Message is 30 seconds or less, and the reported position in the most recently received Position Message differs from the previously reported position by more than **X** NM,

where:
X=6 for Airborne Participants receiving Airborne Position Messages, or
X=2.5 for Airborne Participants that have received a Surface Position Message, or
X=2.5 for Surface Participants that have received an Airborne Position Message, or
X=0.75 for Surface Participants receiving Surface Position Messages,

then the most recently received position **shall not** be used to update the track.

Note: *The position threshold value is based on the assumption of a maximum aircraft velocity of **V** knots (where **V**=600 for Airborne and **V**=50 for Surface) over a maximum time period of 30 seconds. This yields a maximum positional difference of approximately 5 NM for Airborne, and 0.5 NM for Surface. An additional measure of 1 NM for Airborne, and 0.25 NM for Surface are added to account for additional ADS-B positional measurement uncertainty.*

A.1.8 Formats for Extended Squitter

The Extended Squitter messages will be formatted as defined in the following tables.

Note: *In some cases, ARINC 429 labels are referenced for specific message fields. These references are only intended to clarify the field content, and are not intended as a requirement to use these ARINC 429 labels as the source for the message field.*

Figure A-1: Extended Squitter Airborne Position

Register 05_{16}

Bit	Field
1	
2	
3	FORMAT TYPE CODE
4	(§A.1.4.1)
5	
6	
7	SURVEILLANCE STATUS
8	NIC SUPPLEMENT-B (§A.1.4.2.5)
9	
10	
11	ALTITUDE
12	Specified by the Format TYPE Code
13	
14	(1) the altitude code (AC) as specified in §2.2.13.1.2 of
15	DO-181D, but with the M-bit removed (Ref ARINC 429
16	Label 203), or
17	
18	(2) GNSS Height (HAE) (Ref. ARINC 429 Label 370)
19	
20	
21	TIME (T) (§A.1.4.2.2)
22	CPR FORMAT (F) (§A.1.4.2.1)
23	MSB
24	
25	
26	
27	
28	
29	
30	CPR ENCODED LATITUDE
31	
32	(CPR Airborne Format §A.1.7.1 to §A.1.7.7)
33	
34	
35	
36	
37	
38	
39	LSB
40	MSB
41	
42	
43	
44	
45	
46	
47	CPR ENCODED LONGITUDE
48	
49	(CPR Airborne Format §A.1.7.1 to §A.1.7.7)
50	
51	
52	
53	
54	
55	
56	LSB

Purpose: To provide accurate airborne position information.

Surveillance Status Coding

0 = no condition information
1 = permanent alert (emergency condition)
2 = temporary alert (change in Mode A identity code other than emergency condition
3 = SPI condition

Codes 1 and 2 take precedence over code 3.

Note: *When horizontal position information is unavailable, but altitude information is available, the Airborne Position Message is transmitted with a Format TYPE Code of ZERO in bits 1-5 and the barometric pressure altitude in bits 9 to 20. If neither horizontal position nor barometric altitude information is available, then all 56 bits of Register* 05_{16} *are ZEROed. The ZERO Format TYPE Code field indicates that Latitude and Longitude information is unavailable, while the ZERO altitude field indicates that altitude information is unavailable.*

Figure A-2: Extended Squitter Surface Position

Register 06_{16}

Bit		Field
1		
2		
3		FORMAT TYPE CODE
4		(§A.1.4.1)
5		
6		
7		
8		
9		MOVEMENT
10		(§A.1.4.3.1)
11		
12		
13		STATUS for Heading (1 = valid, 0 = not valid)
14	MSB	
15		
16		HEADING (7 bits)
17		(§A.1.4.3.2)
18		Resolution = 360/128 degrees
19		
20	LSB	
21		TIME (T) (§A.1.4.2.2)
22		CPR FORMAT (F) (§A.1.4.2.1)
23	MSB	
24		
25		
26		
27		
28		
29		
30		CPR ENCODED LATITUDE
31		
32		(CPR Surface Format §A.1.7.1 to §A.1.7.7)
33		
34		
35		
36		
37		
38		
39	LSB	
40	MSB	
41		
42		
43		
44		
45		
46		
47		CPR ENCODED LONGITUDE
48		
49		(CPR Surface Format §A.1.7.1 to §A.1.7.7)
50		
51		
52		
53		
54		
55		
56	LSB	

Purpose: To provide accurate surface position information.

Figure A-3: Extended Squitter Status

Register 07_{16}

Bit	Field
1	TRANSMISSION RATE SUBFIELD (TRS)
2	
3	ALTITUDE TYPE SUBFIELD (ATS)
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	RESERVED
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	

Purpose: To provide information on the capability and status of the Extended Squitter rate of the transponder.

Transmission Rate Subfield (TRS) coding:
0 = No capability to determine surface squitter rate
1 = High surface squitter rate selected
2 = Low surface squitter rate selected
3 = Reserved

Altitude Type Subfield (ATS) coding:
0 = Barometric altitude
1 = GNSS Height (HAE), ARINC 429 Label 370

Note: *Aircraft determination of surface squitter rate. For aircraft that have the capability to automatically determine their surface squitter rate, the method that must be used to switch between the high and low transmission rates is as follows:*

a) Switching from high to low rate: Aircraft must switch from high to low rate when the onboard navigation unit reports that the aircraft's position has not changed more than 10 meters in any 30 second interval.

b) Switching from low to high rate: Aircraft must switch from low to high rate as soon as the aircraft's position has changed by 10 meters, or more since the low rate was selected.

In all cases, the automatically selected transmission rate is subject to being overridden by commands received from ground control.

Figure A-4: Extended Squitter Identification and Category

Register 08_{16}

Bits	Field
1–5	FORMAT TYPE CODE (§A.1.4.1)
6–8	AIRCRAFT EMITTER CATEGORY
9 (MSB) – 14 (LSB)	CHARACTER 1
15 (MSB) – 20 (LSB)	CHARACTER 2
21 (MSB) – 26 (LSB)	CHARACTER 3
27 (MSB) – 32 (LSB)	CHARACTER 4
33 (MSB) – 38 (LSB)	CHARACTER 5
39 (MSB) – 44 (LSB)	CHARACTER 6
45 (MSB) – 50 (LSB)	CHARACTER 7
51 (MSB) – 56 (LSB)	CHARACTER 8

Purpose: To provide aircraft identification and category.

TYPE Coding:
1 = Aircraft identification, Category Set D
2 = Aircraft identification, Category Set C
3 = Aircraft identification, Category Set B
4 = Aircraft identification, Category Set A

ADS-B Aircraft Emitter Category coding:

Set A

0 = No ADS-B Emitter Category Information
1 = Light (< 15500 lbs)
2 = Small (15500 to 75000 lbs)
3 = Large (75000 to 300000 lbs)
4 = High Vortex Large (aircraft such as B-757)
5 = Heavy (> 300000 lbs)
6 = High Performance (> 5g acceleration and 400 kts)
7 = Rotorcraft

Set B

0 = No ADS-B Emitter Category Information
1 = Glider / sailplane
2 = Lighter-than-air
3 = Parachutist / Skydiver
4 = Ultralight / hang-glider / paraglider
5 = Reserved
6 = Unmanned Aerial Vehicle
7 = Space / Trans-atmospheric vehicle

Set C

0 = No ADS-B Emitter Category Information
1 = Surface Vehicle – Emergency Vehicle
2 = Surface Vehicle – Service Vehicle
3 = Point Obstacle (includes tethered balloons)
4 = Cluster Obstacle
5 = Line Obstacle
6 = Reserved
7 = Reserved

Set D (Reserved)

Aircraft Identification coding:
Character coding as specified in §A.1.4.4.

Figure A-5: Extended Squitter Airborne Velocity (Subtypes 1 and 2: Velocity Over Ground)

Register 09_{16}

Bit				
1	MSB			**1**
2				**0**
3	FORMAT TYPE CODE = 19			**0**
4				**1**
5	LSB			**1**
6	Subtype 1	0	Subtype 2	0
7		0		1
8		1		0
9	INTENT CHANGE FLAG (§A.1.4.5.3)			
10	RESERVED-A			
11–13	NAVIGATION ACCURACY CATEGORY FOR VELOCITY (NAC_V) (§A.1.4.5.5)			
14	DIRECTION BIT for E-W Velocity (**0=East, 1=West**)			
15	EAST-WEST VELOCITY (10 bits)			
16	NORMAL : LSB = 1 knot		SUPERSONIC : LSB = 4 knots	
17	All zeros = no velocity info		All zeros = no velocity info	
18	Value	Velocity	Value	Velocity
19	1	0 kts	1	0 kts
20	2	1 kt	2	4 kts
21	3	2 kts	3	8 kts
22	---	---	---	---
23	1022	1021 kts	1022	4084 kts
24	1023	>1021.5 kts	1023	> 4086 kts
25	DIRECTION BIT for N-S Velocity (**0=North, 1=South**)			
26	NORTH – SOUTH VELOCITY (10 bits)			
27	NORMAL : LSB = 1 knot		SUPERSONIC : LSB = 4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kts
31	2	1 kt	2	4 kts
32	3	2 kts	3	8 kts
33	---	---	---	---
34	1022	1021 kts	1022	4084 kts
35	1023	> 1021.5 kts	1023	> 4086 kts
36	SOURCE BIT FOR VERTICAL RATE (0=Geometric, 1=Baro)			
37	SIGN BIT FOR VERTICAL RATE (0=Up, 1=Down)			
38	VERTICAL RATE (9 bits)			
39	All zeros – no vertical rate info, LSB = 64 feet/min			
40	Value	Vertical Rate	Reference	
41	1	0 ft/min	ARINC 429 labels	
42	2	64 ft/min	GPS: 165	
43	---	---	INS: 365	
44	510	32576 ft/min		
45	511	> 32608 ft/min		
46				
47–48	RESERVED-B			
49	DIFFERENCE SIGN BIT (0 = Above Baro, 1 = Below Baro Alt)			
50	GEOMETRIC HEIGHT DIFFERENCE FROM BARO ALT. (7 bits) (§A.1.4.5.7) (All zeros = no info) (LSB = 25 feet)			
51	Value	Difference		
52	1	0 feet		
53	2	25 feet		
54	---	---		
55	126	3125 feet		
56	127	> 3137.5 feet		

Purpose: To provide additional state information for both normal and supersonic flight.

Subtype Coding:

Code	Velocity	Type
0	Reserved	
1	Ground Speed	Normal
2	Ground Speed	Supersonic
3	Airspeed, Heading	Normal
4	Airspeed, Heading	Supersonic
5	Not Assigned	
6	Not Assigned	
7	Not Assigned	

Reference ARINC Labels for Velocity:

East - West	North - South
GPS: 174	GPS: 166
INS: 367	INS: 366

Reference ARINC Labels:

GNSS Height (HAE): GPS 370
GNSS Altitude (MSL): GPS: 076

Figure A-6: Extended Squitter Airborne Velocity (Subtypes 3 and 4: Airspeed and Heading)

Register 09_{16}

Bit				
1	MSB		**1**	
2			**0**	
3	FORMAT TYPE CODE = 19		**0**	
4			**1**	
5	LSB		**1**	
6	Subtype 3	0	Subtype 4	1
7		1		0
8		1		0
9	INTENT CHANGE FLAG (§A.1.4.5.3)			
10	RESERVED-A			
11				
12	NAVIGATION ACCURACY CATEGORY FOR VELOCITY (NAC_V) (§A.1.4.5.5)			
13				
14	STATUS BIT (1 = Heading available, 0 = Not available)			
15	MSB			
16				
17				
18	HEADING (10 bits)			
19	(§A.1.4.5.6)			
20	Resolution = 360/1024 degrees			
21				
22			Reference ARINC Label	
23			INS: 320	
24	LSB			
25	AIRSPEED TYPE (0 = IAS, 1 = TAS)			
26	AIRSPEED (10 bits)			
27	NORMAL: LSB = 1 knot		SUPERSONIC: LSB = 4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kts
31	2	1 kt	2	4 kts
32	3	2 kts	3	8 kts
33	---	---	---	---
34	1022	1021 kts	1022	4084 kts
35	1023	> 1021.5 kts	1023	> 4086 kts
36	SOURCE BIT FOR VERTICAL RATE (0=Geo, 1=Baro)			
37	SIGN BIT FOR VERTICAL RATE (0=Up, 1=Down)			
38	VERTICAL RATE (9 bits)			
39	All zeros – no vertical rate information			
40	LSB = 64 feet/min			
41	Value	Vertical Rate	Reference	
42	1	0 ft/min	ARINC Labels	
43	2	64 ft/min	GPS: 165	
44	---	---	INS: 365	
45	510	32576 ft/min		
46	511	> 32608 ft/min		
47				
48	RESERVED-B			
49	DIFFERENCE SIGN BIT (0 = Above Baro, 1 = Below Baro Alt)			
50	GEOMETRIC HEIGHT DIFFERENCE FROM BARO ALT (7 bits) (§A.1.4.5.7) (All zeros = no info) (LSB = 25 feet)			
51	Value	Vertical Rate		
52	1	0 ft		
53	2	25 ft		
54	---	---		
55	126	3125 ft		
56	127	> 3137.5 ft		

Purpose: To provide additional state information for both normal and supersonic flight based on airspeed and heading.

Note: *This format is only used if velocity over ground is not available.*

Subtype Coding:

Code	Velocity	Type
0	Reserved	
1	Ground Speed	Normal
2	Ground Speed	Supersonic
3	Airspeed, Heading	Normal
4	Airspeed, Heading	Supersonic
5	Not Assigned	
6	Not Assigned	
7	Not Assigned	

Reference ARINC 429 Labels for Air Data Source:

IAS: 206
TAS: 210

Reference ARINC Labels:

GNSS Height (HAE): GPS 370
GNSS Altitude (MSL): GPS: 076

Figure A-7: Extended Squitter Event-Driven Register

Register $0A_{16}$

1	
2	
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36	
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39	
40	
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43	
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49	
50	
51	
52	
53	
54	
55	
56	

Purpose: To provide a flexible means to squitter messages other than position, velocity and identification.

Note: *The data in this Register is not intended for Extraction using GICB or TCAS crosslink protocols. Readout (if required) is accomplished by extracting the Contents of the appropriate Register* 61_{16} *to* $6F_{16}$.

Figure A-8a: Extended Squitter Aircraft Status (Subtype 1: Emergency/Priority Status and Mode A Code)

Register 61_{16}

Bit	Field
1	MSB
2	
3	FORMAT TYPE CODE = 28
4	
5	LSB
6	MSB
7	SUBTYPE CODE = 1
8	LSB
9	MSB
10	EMERGENCY STATE
11	LSB
12	MSB
13	
14	
15	
16	
17	MODE A (4096) CODE
18	
19	
20	
21	
22	
23	
24	LSB
25–56	RESERVED

PURPOSE: To provide additional information on aircraft status.

Subtype shall be coded as follows:

0 = No information
1 = Emergency/Priority Status and Mode A Code
2 = TCAS RA Broadcast
3 to 7 = Reserved

Emergency state shall be coded as follows:

Value	Meaning
0	No emergency
1	General emergency
2	Lifeguard/Medical
3	Minimum fuel
4	No communications
5	Unlawful interference
6	Downed aircraft
7	Reserved

Notes:

1) *Message delivery is accomplished once per 0.8 seconds using the Event-Driven protocol.*

2) *Termination of emergency state is detected by coding in the surveillance status field of the Airborne Position Message.*

3) *Subtype 2 message broadcasts take priority over Subtype 1 message broadcasts.*

4) *Emergency State value 1 is set when Mode A code 7700 is provided to the transponder.*

5) *Emergency State value 4 is set when Mode A code 7600 is provided to the transponder.*

6) *Emergency State value 5 is set when Mode A code 7500 is provided to the transponder.*

Figure A-8b: Extended Squitter Aircraft Status (Subtype 2: 1090ES TCAS RA Broadcast)

Register 61_{16}

Bit	Field
1	MSB
2	
3	FORMAT TYPE CODE = 28
4	
5	LSB
6	MSB
7	Subtype CODE = 2
8	LSB
9	MSB
10	
11	
12	
13	
14	
15	ACTIVE RESOLUTION ADVISORIES
16	
17	
18	
19	
20	
21	
22	LSB
23	MSB
24	RACs RECORD
25	
26	LSB
27	RA TERMINATED
28	MULTIPLE THREAT ENCOUNTER
29	MSB THREAT – TYPE INDICATOR
30	LSB
31	MSB
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	THREAT IDENTITY DATA
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	LSB

PURPOSE: To report resolution advisories (RAs) generated by TCAS equipment.

Subtype Coding:

0	=	No information
1	=	Emergency/Priority Status
2	=	TCAS RA Broadcast
3 to 7	=	Reserved

TCAS RA Broadcast Coding:

The coding of bits 9 to 56 of this Message conforms to the corresponding bits of Register 30_{16} as specified in Annex 10, Volume IV, §4.3.8.4.2.2.

Notes:

1) *Message delivery is accomplished once per 0.8 seconds using the event-driven protocol.*

2) *RA Broadcast begins within 0.5 seconds after transponder notification of the initiation of an TCAS RA.*

3) *RA Broadcast is terminated 24 ±1 seconds after the RAT flag (Annex 10, Volume IV, §4.3.8.4.2.2.1.3) transitions from ZERO (0) to ONE (1).*

4) *Subtype 2 message broadcasts take priority over subtype 1 message broadcasts.*

Figure A-9a: Target State and Status Information
(Subtype = 0: Compatible with DO-260A, ADS-B Version Number=1)

Register 62_{16}

Bit		Field
1		FORMAT TYPE CODE = 29
2		
3		
4		
5		
6	MSB	SUBTYPE CODE = 0
7	LSB	
8	MSB	Vertical Data Available / Source Indicator (§A.1.4.9.3)
9	LSB	
10		Target Altitude Type (§A.1.4.9.4)
11		Backward Compatibility Flag = 0
12	MSB	Target Altitude Capability (§A.1.4.9.5)
13	LSB	
14	MSB	Vertical Mode Indicator (§A.1.4.9.6)
15	LSB	
16	MSB	Target Altitude (§A.1.4.9.7)
17		
18		
19		
20		
21		
22		
23		
24		
25	LSB	
26	MSB	Horizontal Data Available / Source Indicator (§A.1.4.9.8)
27	LSB	
28	MSB	Target Heading / Track Angle (§A.1.4.9.9)
29		
30		
31		
32		
33		
34		
35		
36	LSB	
37		Target Heading / Track Indicator (§A.1.4.9.10)
38	MSB	Horizontal Mode Indicator (§A.1.4.9.11)
39	LSB	
40	MSB	Navigation Accuracy Category – Position (NAC_P) (§A.1.4.9.12)
41		
42		
43	LSB	
44		Navigation Integrity Category – Baro (NIC_{BARO}) (§A.1.4.9.13)
45	MSB	Surveillance Integrity Level (SIL) (§A.1.4.9.14)
46	LSB	
47		Reserved
48		
49		
50		
51		
52	MSB	Capability / Mode Codes (§A.1.4.9.15)
53	LSB	
54	MSB	Emergency / Priority Status (§A.1.4.9.16)
55		
56	LSB	

PURPOSE: To provide aircraft state and status information.

Figure A-9b: Target State and Status Information (Subtype = 1: Compatible with DO-260B, ADS-B Version Number=2)

Register 62_{16}

Bit	Field
1	
2	
3	**FORMAT TYPE CODE = 29**
4	
5	
6	MSB **SUBTYPE CODE = 1**
7	LSB
8	**SIL SUPPLEMENT** (0=Per Hour, 1=Per Sample)
9	**SELECTED ALTITUDE TYPE** (0=MCP/FCU, 1=FMS)
10	MSB = 32768 feet
11	**MCP / FCU SELECTED ALTITUDE**
12	(when Selected Altitude Type = 0)
13	**FMS SELECTED ALTITUDE**
14	(when Selected Altitude Type = 1)
15	Coding: 111 1111 1111 = 65472 feet
16	*** **** ****
17	000 0000 0010 = 32 feet
18	000 0000 0001 = 0 feet
19	000 0000 0000 = No data or Invalid
20	LSB = 32 feet
21	MSB = 204.8 millibars
22	**BAROMETRIC PRESSURE SETTING (MINUS 800 millibars)**
23	Range = [0, 408.0] Resolution = 0.8 millibars
24	Coding: 1 1111 1111 = 408.00 millibars
25	* **** ****
26	0 0000 0010 = 0.800 millibars
27	0 0000 0001 = 0.000 millibars
28	0 0000 0000 = No Data or Invalid
29	LSB = 0.8 millibars
30	STATUS (0=Invalid, 1=Valid)
31	Sign (0=Positive, 1=Negative)
32	MSB = 90.0 degrees
33	
34	**SELECTED HEADING**
35	Range = [+/- 180] degrees, Resolution = 0.703125 degrees
36	(Typical Selected Heading Label = "101")
37	
38	
39	LSB = 0.703125 degrees (180/256)
40	MSB
41	**NAVIGATION ACCURACY CATEGORY FOR POSITION (NAC_P)**
42	(§A.1.4.9.9)
43	LSB
44	**NAVIGATION INTEGRITY CATEGORY FOR BARO (NIC_{BARO})**
45	MSB **SOURCE INTEGRITY LEVEL (SIL)**
46	LSB
47	**STATUS OF MCP / FCU MODE BITS** (0 = Invalid, 1 = Valid)
48	**AUTOPILOT ENGAGED** (0 = Not Engaged, 1 = Engaged)
49	**VNAV MODE ENGAGED** (0 = Not Engaged, 1 = Engaged)
50	**ALTITUDE HOLD MODE** (0 = Not Engaged, 1 = Engaged)
51	**Reserved for ADS-R Flag** (see §2.2.18.4.6)
52	**APPROACH MODE** (0 = Not Engaged, 1 = Engaged)
53	**TCAS OPERATIONAL** (0 = Not Operational, 1 = Operational)
54	MSB
55	**RESERVED**
56	LSB

PURPOSE: To provide aircraft state and status information.

Figure A-10: Aircraft Operational Status

Register 65_{16}

1	MSB	
2		
3	FORMAT TYPE CODE = 31	
4		
5	LSB	
6	MSB	MSB
7	SUBTYPE CODE = 0	SUBTYPE CODE = 1
8	LSB	LSB
9	MSB	MSB
10		
11		
12		
13		
14	AIRBORNE	SURFACE
15	CAPABILITY CLASS (CC)	CAPABILITY CLASS (CC)
16	CODES	CODES
17	(§A.1.4.10.3)	(§A.1.4.10.3)
18		
19		
20		LSB
21		MSB
22		LENGTH/WIDTH CODES
23		(§A.1.4.10.11)
24	LSB	LSB
25	MSB	MSB
26		
27		
28		
29		
30	AIRBORNE	SURFACE
31	OPERATIONAL	OPERATIONAL
32	MODE (OM) CODES	MODE (OM) CODES
33	(§A.1.4.10.4)	(§A.1.4.10.4)
34		
35		
36		
37		
38		
39		
40	LSB	LSB
41	MSB	
42	VERSION NUMBER (§A.1.4.10.5)	
43	LSB	
44	NIC SUPPLEMENT-A (§A.1.4.10.6)	
45	MSB	
46	NAVIGATIONAL ACCURACY CATEGORY – POSITION	
47	(NAC_P) (§A.1.4.10.7)	
48	LSB	
49	MSB GVA	RESERVED
50	LSB (§A.1.4.10.8)	
51	MSB SOURCE INTEGRITY LEVEL (SIL)	
52	LSB (§A.1.4.10.9)	
53	NIC_{BARO} (§A.1.4.10.10)	TRK/HDG (§A.1.4.10.12)
54	HRD (§A.1.4.10.13)	
55	SIL SUPPLEMENT (§A.1.4.10.14)	
56	RESERVED	

PURPOSE: To provide the capability class and current operational mode of ATC-related applications and other operational information..

Subtype Coding:

0 = Airborne Status Message
1 = Surface Status Message
2 – 7 = Reserved

A.2 Traffic Information Services – Broadcast (TIS-B) Formats and Coding

A.2.1 Introduction

Notes:

1. *This section of Appendix A defines the formats and coding for a Traffic Information Service Broadcast (TIS-B) based on the same 112-bit 1090 MHz signal transmission that is used for ADS-B on 1090 MHz.*

2. *TIS-B complements the operation of ADS-B by providing ground-to-air broadcast of surveillance data on aircraft that are not equipped for 1090 MHz ADS-B. The basis for this ground surveillance data may be an ATC Mode S radar, a surface or approach multi-lateration system or a multi-sensor data processing system. The TIS-B ground-to-air transmissions use the same signal formats as 1090 MHz ADS-B and can therefore be accepted by a 1090 MHz ADS-B receiver.*

3. *TIS-B service is the means for providing a complete surveillance picture to 1090 MHz ADS-B users during a transition period. After transition, it also provides a means to cope with a user that has lost its 1090 MHz ADS-B capability, or is broadcasting incorrect information.*

A.2.2 TIS-B Format Definition

TIS-B information is broadcast using the 112-bit Mode S DF=18 format as shown below in Figure A-11.

TIS-B Format Definition					
Bit #	1 ----- 5	6 --- 8	9 ----- 32	33 -------------------------- 88	89 ---- 112
DF=18 Field Names	**DF [5]**	**CF [3]**	**AA [24]**	**ME [56]**	**PI [24]**
	10010				
	MSB LSB	MSB LSB	MSB LSB	MSB LSB	MSB LSB

Figure A-11: TIS-B Format Definition

A.2.3 Control Field Allocation

The content of the DF=18 transmission is defined by the value of the control field, as specified in Table A-29.

Table A-29: CF Field Code Definitions in DF=18 ADS-B and TIS-B Messages

CF Value	ICAO/Mode A Flag (IMF)	Meaning
0	N/A	ADS-B Message from a non-transponder device, AA field holds 24-bit ICAO aircraft address
1	N/A	Reserved for ADS-B Message in which the AA field holds anonymous address or ground vehicle address or fixed obstruction address
2	0	Fine TIS-B Message, AA field contains the 24-bit ICAO aircraft address
	1	Fine TIS-B Message, AA field contains the 12-bit Mode A code followed by a 12-bit track file number
3	0	Coarse TIS-B Airborne Position and Velocity Message, AA field contains the 24-bit ICAO aircraft address
	1	Coarse TIS-B Airborne Position and Velocity Message, AA field contains the 12-bit Mode A code followed by a 12-bit track file number.
4	N/A	TIS-B and ADS-R Management Message AA field contains TIS-B/ADS-R management information.
5	0	Fine TIS-B Message AA field contains a non-ICAO 24-bit address
	1	Reserved
6	0	Rebroadcast of ADS-B Message from an alternate data link AA field holds 24-bit ICAO aircraft address
	1	Rebroadcast of ADS-B Message from an alternate data link AA field holds anonymous address or ground vehicle address or fixed obstruction address
7	N/A	Reserved

A.2.4 TIS-B Surveillance Message Definition

A.2.4.1 TIS-B Fine Airborne Position Message

The TIS-B fine airborne position ME field will be formatted as specified in Figure A-12.

Note: *Additional details are specified in the following paragraphs.*

A.2.4.1.1 ICAO/Mode A Flag (IMF)

This one-bit field (bit 8) will indicate the type of identity associated with the aircraft data reported in the TIS-B message. IMF equal to ZERO (0) will indicate that the TIS-B data is identified by an ICAO 24-bit address. IMF equal to ONE (1) will indicate that the TIS-B data is identified by a "Mode A" code. A TIS-B report on a primary radar target will indicate a "Mode A" code of all ZEROs.

Notes:

1. *The AA field is coded differently for 24-bit addresses and Mode A codes as specified in Table A-22.*

2. *A target with a ZERO "Mode A" code and a reported altitude is an SSR target.*

A.2.4.1.2 Pressure Altitude

This 12-bit field will provide the aircraft pressure altitude. This field will contain barometric altitude encoded in 25 or 100-foot increments (as indicated by the Q Bit). All zeroes in this field will indicate that there is no altitude data.

A.2.4.1.3 Compact Position Reporting (CPR) Format (F)

This field will be set as specified in §A.1.4.2.1.

A.2.4.1.4 Latitude/Longitude

The Latitude/Longitude fields in the TIS-B fine Airborne Position Message will be set as specified in §A.1.4.2.3.

A.2.4.2 TIS-B Surface Position Message

The TIS-B surface position ME field will be formatted as specified in Figure A-13.

Note: *Additional details are specified in the following paragraphs.*

A.2.4.2.1 Movement

This field will be set as specified in §A.1.4.3.1.

A.2.4.2.1.1 Ground Track (True)

A.2.4.2.1.1.1 Ground Track Status

This field will be set as specified in §A.1.4.3.2.1.

A.2.4.2.1.1.2 Ground Track Angle

This field will be set as specified in §A.1.4.3.2.2.

A.2.4.2.1.2 ICAO/Mode A Flag (IMF)

This one-bit field (bit 21) will indicate the type of identity associated with the aircraft data reported in the TIS-B message. Coding is specified in §A.2.4.1.1.

A.2.4.2.1.3 Compact Position Reporting (CPR) Format (F)

This field will be set as specified in §A.1.4.3.3.

A.2.4.2.1.4 Latitude/Longitude

The Latitude/Longitude fields in the TIS-B fine Surface Position Message will be set as specified in §A.1.4.3.5.

A.2.4.3 Identification and Category Message

The TIS-B identification and category ME field will be formatted as specified in Figure A-14. This message will only be used for aircraft identified with an ICAO 24-bit address.

Note: *Additional details are specified in the following paragraphs.*

A.2.4.3.1 Aircraft Identification Coding

This field will be set as specified in §A.1.4.4.1.

A.2.4.4 Velocity Message

The TIS-B Velocity ME field will be formatted as specified in the Figure A-15 for Subtypes 1 and 2, and in Figure A-16 for Subtypes 3 and 4.

Note: *Additional details are specified in the following paragraphs.*

A.2.4.4.1 Subtype Field

Subtypes 1 through 4 will be used for the TIS-B Velocity Message. Subtype 1 will be used for velocities over ground under 1000 knots and Subtype 2 will be used for aircraft capable of supersonic flight when the velocity over ground might exceed 1022 knots.

The supersonic version of the velocity coding will be used if either the East-West OR North-South velocities exceed 1022 knots. A switch to the normal velocity coding will be made if both the East-West AND North-South velocities drop below 1000 knots.

Subtypes 3 and 4 will be used when Airspeed and Heading are substituted for velocity over ground. Subtype 3 will be used at subsonic airspeeds, while Subtype 4 will be used for aircraft capable of supersonic flight when the Airspeed might exceed 1022 knots.

The supersonic version of the Airspeed coding will be used if the Airspeed exceeds 1022 knots. A switch to the normal Airspeed coding will be made if the Airspeed drops below 1000 knots.

A.2.4.4.2 ICAO/Mode A Flag (IMF)

This one-bit field (bit 9) will indicate the type of identity associated with the aircraft data reported in the TIS-B message. Coding is specified in §A.2.4.1.1.

A.2.4.5 Coarse Airborne Position Message

The TIS-B coarse airborne position ME field will be formatted as specified in Figure A-17.

Notes:

1. *This message is used if the surveillance source for TIS-B is not of high enough quality to justify the use of the fine formats. An example of such a source is a scanning beam Mode S interrogator.*

2. *Additional details are specified in the following paragraphs.*

A.2.4.5.1 ICAO/Mode A Flag (IMF)

This one-bit field (bit 1) will indicate the type of identity associated with the aircraft data reported in the TIS-B message. Coding is specified in §A.2.4.1.1.

A.2.4.5.2 Service Volume ID (SVID)

The 4-bit SVID field will identify the TIS-B site that delivered the surveillance data.

Note: *In the case where TIS-B messages are being received from more than one TIS-B ground stations, the SVID can be used to select coarse messages from a single source. This will prevent the TIS-B track from wandering due to the different error biases associated with different sources.*

A.2.4.5.3 Pressure Altitude

This 12-bit field will provide the aircraft pressure altitude. This field will contain barometric altitude encoded in 25 or 100-foot increments (as indicated by the Q Bit).

A.2.4.5.4 Ground Track Status

This one bit (ME bit 20) field will define the validity of the ground track value. Coding for this field will be as follows: 0=not valid and 1= valid.

A.2.4.5.5 Ground Track Angle

This 5-bit (ME bits 21-25) field will define the direction (in degrees clockwise from true north) of aircraft motion. The ground track will be encoded as an unsigned angular weighted binary numeral, with an MSB of 180 degrees and an LSB of 360/32 degrees, with ZERO (0) indicating true north. The data in the field will be rounded to the nearest multiple of 360/32 degrees.

A.2.4.5.6 Ground Speed

This 6-bit (ME bits 26-31) field will define the aircraft speed over the ground. Coding of this field will be as specified in §2.2.17.3.5.6.

A.2.4.5.7 Latitude/Longitude

The Latitude/Longitude fields in the TIS-B Coarse Airborne Position Message will be set as specified in §A.1.4.2.3, except that the 12-bit form of CPR coding will be used.

A.2.5 TIS-B and ADS-R Management Messages

The TIS-B/ADS-R Management Messages use Extended Squitter format DF=18 and CF=4 to provide information related to the provision of the TIS-B and/or ADS-R Service Volume in the specific airspace being serviced by the local ground broadcast site(s).

The TIS-B/ADS-R Management Message is used to provide a specific announcement of the Service Volume and the service availability in local airspace where the TIS-B and/or ADS-R service is being supported by the ground infrastructure.

A.2.6 Formats for 1090 MHz TIS-B Messages

Figure A-12: TIS-B Fine Airborne Position Message

1	
2	
3	FORMAT TYPE CODE
4	(See §A.1.4.1 and Note 1)
5	
6	MSB SURVEILLANCE STATUS
7	LSB
8	IMF (§A.2.4.1.1)
9	
10	
11	
12	
13	PRESURE ALTITUDE
14	
15	
16	The altitude code (AC) as specified in §2.2.13.1.2 of
17	DO-181D, but with the M-bit removed.
18	
19	
20	
21	RESERVED
22	CPR FORMAT (F) (§A.1.4.2.1)
23	MSB
24	
25	
26	
27	
28	
29	CPR ENCODED LATITUDE
30	CPR Airborne Format
31	(§A.1.7.1 to §A.1.7.7)
32	
33	
34	
35	
36	
37	
38	
39	LSB
40	MSB
41	
42	
43	
44	
45	
46	CPR ENCODED LONGITUDE
47	CPR Airborne Format
48	(§A.1.7.1 to §A.1.7.7)
49	
50	
51	
52	
53	
54	
55	
56	LSB

Purpose: To provide airborne position information for aircraft that are not equipped with 1090 MHz ADS-B service is based on high quality surveillance data.

Surveillance Status coding:
0 = no condition information
1 = permanent alert (emergency condition)
2 = temporary alert (change in Mode A identity code other than emergency condition)
3 = SPI condition

Codes 1 and 2 take precedence over code 3.

Figure A-13: TIS-B Fine Surface Position Message

Purpose: To provide surface position information for aircraft that are not equipped with 1090 MHz ADS-B.

1	
2	
3	FORMAT TYPE CODE
4	(§A.1.4.1)
5	
6	
7	
8	
9	MOVEMENT
10	(§A.1.4.3.1)
11	
12	
13	STATUS for Heading/Ground Track (1=valid, 0=not valid)
14	MSB
15	
16	HEADING / GROUND TRACK (7 bits)
17	(Referenced to true north)
18	Resolution = 360/128 degrees
19	
20	LSB
21	IMF (§A.2.4.2.1.2)
22	CPR FORMAT (F) (§A.1.4.2.1)
23	MSB
24	
25	
26	
27	
28	
29	
30	CPR ENCODED LATITUDE
31	CPR Surface Format
32	(§A.1.7.1 to §A.1.7.7)
33	
34	
35	
36	
37	
38	
39	LSB
40	MSB
41	
42	
43	
44	
45	
46	
47	CPR ENCODED LONGITUDE
48	CPR Surface Format
49	(§A.1.7.1 to §A.1.7.7)
50	
51	
52	
53	
54	
55	
56	LSB

Figure A-14: TIS-B Identification and Category Message

Bits	MSB	LSB	Field
1–5			FORMAT TYPE CODE (§A.1.4.1)
6–8			AIRCRAFT EMITTER CATEGORY
9–14	9	14	CHARACTER 1
15–20	15	20	CHARACTER 2
21–26	21	26	CHARACTER 3
27–32	27	32	CHARACTER 4
33–38	33	38	CHARACTER 5
39–44	39	44	CHARACTER 6
45–50	45	50	CHARACTER 7
51–56	51	56	CHARACTER 8

Purpose: To provide aircraft identification and category for aircraft that are not equipped with 1090 MHz ADS-B.

TYPE Coding:
1 = Aircraft identification, Category Set D
2 = Aircraft identification, Category Set C
3 = Aircraft identification, Category Set B
4 = Aircraft identification, Category Set A

ADS-B Aircraft Emitter Category coding:

Set A

0 = No ADS-B Emitter Category Information
1 = Light (< 15500 lbs)
2 = Small (15500 to 75000 lbs)
3 = Large (75000 to 300000 lbs)
4 = High Vortex Large (aircraft such as B-757)
5 = Heavy (> 300000 lbs)
6 = High Performance (> 5g acceleration and 400 kts)
7 = Rotorcraft

Set B

0 = No ADS-B Emitter Category Information
1 = Glider / sailplane
2 = Lighter-than-air
3 = Parachutist / Skydiver
4 = Ultralight / hang-glider / paraglider
5 = Reserved
6 = Unmanned Aerial Vehicle
7 = Space / Trans-atmospheric vehicle

Set C

0 = No ADS-B Emitter Category Information
1 = Surface Vehicle – Emergency Vehicle
2 = Surface Vehicle – Service Vehicle
3 = Point Obstacle (includes tethered balloons)
4 = Cluster Obstacle
5 = Line Obstacle
6 = Reserved
7 = Reserved

Set D
(Reserved)

Aircraft Identification coding:
Character coding as specified in §A.1.4.4.

Figure A-15: TIS-B Velocity Messages (Subtypes 1 and 2: Velocity Over Ground)

Purpose: To provide velocity information for aircraft that are not equipped with 1090 MHz ADS-B when the TIS-B service is based on high quality surveillance data.

Subtype Coding:

Code	Velocity	Type
1	Ground	Normal
2	Speed	Supersonic

Note: *The "Vertical Rate" and "Geometric Height Difference From Barometric" fields for surface aircraft do not need to be processed by TIS-B receivers.*

Bit				
1	MSB			**1**
2				**0**
3	FORMAT TYPE CODE = 19			**0**
4				**1**
5	LSB			**1**
6	Subtype 1	0	Subtype 2	0
7		0		1
8		1		0
9	IMF (§A.2.4.4.2)			
10	MSB			
11	NAVIGATION ACCURACY CATEGORY FOR POSITION			
12	(NAC_P) (§A.1.4.10.7)			
13	LSB			
14	DIRECTION BIT for E-W Velocity (**0=East, 1=West**)			
15	EAST-WEST VELOCITY (10 bits)			
16	NORMAL : LSB = 1 knot		SUPERSONIC : LSB = 4 knots	
17	All zeros = no velocity info		All zeros = no velocity info	
18	Value	Velocity	Value	Velocity
19	1	0 kts	1	0 kts
20	2	1 kt	2	4 kts
	3	2 kts	3	8 kts
22	---	---	---	---
23	1022	1021 kts	1022	4084 kts
24	1023	>1021.5 kts	1023	> 4086 kts
25	DIRECTION BIT for N-S Velocity (**0=North, 1=South**)			
26	NORTH – SOUTH VELOCITY (10 bits)			
27	NORMAL : LSB = 1 knot		SUPERSONIC : LSB = 4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kts
31	2	1 kt	2	4 kts
32	3	2 kts	3	8 kts
33	---	---	---	---
34	1022	1021 kts	1022	4084 kts
35	1023	> 1021.5 kts	1023	> 4086 kts

Bit	GEO = 0		GEO = 1	
36	GEO FLAG BIT (1 bit) (GEO = 0)		GEO FLAG BIT (1 bit) (GEO = 1)	
37	SIGN BIT FOR VERTICAL RATE (0=Up, 1=Down)		SIGN BIT FOR VERTICAL RATE (0=Up, 1=Down)	
38	VERTICAL RATE (9 bits)		VERTICAL RATE (9 bits)	
39	All zeros – no vertical rate info, LSB = 64 feet/min		All zeros – no vertical rate info, LSB = 64 feet/min	
40	Value	Vertical Rate	Value	Vertical Rate
41	1	0 ft/min	1	0 ft/min
42	2	64 ft/min	2	64 ft/min
43	---	---	---	---
44	510	32576 ft/min	510	32576 ft/min
45	511	> 32608 ft/min	511	> 32608 ft/min
46				
47	NIC SUPPLEMENT (§A.1.4.10.6)		NIC SUPPLEMENT (§A.1.4.10.6)	
48			RESERVED (1 bit)	
49	NAVIGATION ACCURACY CATEGORY FOR VELOCITY		DIFFERENCE SIGN BIT (0 = Above Baro, 1 = Below Baro Alt)	
50	(NAC_V) (§A.1.4.5.5)		GEOMETRIC HEIGHT DIFFERENCE FROM BARO ALT. (7 bits) (§A.1.4.5.7) (All zeros = no info) (LSB = 25 feet)	
51	SURVEILLANCE INTEGRITY LEVEL (SIL)		Value	Difference
52	(§A.1.4.10.9)		1	0 feet
53			2	25 feet
54	RESERVED (4 bits)		---	---
55			126	3125 feet
56			127	> 3137.5 feet

Figure A-16: TIS-B Velocity Messages (Subtypes 3 and 4: Air Referenced Velocity)

Bit	Field	
1	MSB	**1**
2		**0**
3	FORMAT TYPE CODE = 19	**0**
4		**1**
5	LSB	**1**
6	Subtype 3 0	Subtype 4 1
7	1	0
8	1	0
9	IMF (§A.2.4.4.2)	
10–13	NAVIGATION ACCURACY CATEGORY FOR POSITION (NAC_P) (§A.1.4.10.7)	
14	HEADING STATUS BIT (1 = Available, 0 = Not Available)	
15	MSB	
16–23	HEADING (10 bits) (§A.1.4.5.6) Resolution = 360/1024 degrees	
24	LSB	
25	AIRSPEED TYPE (0 = IAS, 1 = TAS)	
26	AIRSPEED (10 bits)	
27	NORMAL: LSB = 1 knot	SUPERSONIC: LSB = 4 knots
28	All zeros = no velocity info	All zeros = no velocity info
29	Value / Velocity	Value / Velocity
30	1 / 0 kts	1 / 0 kts
31	2 / 1 kt	2 / 4 kts
32	3 / 2 kts	3 / 8 kts
33	--- / ---	--- / ---
34	1022 / 1021 kts	1022 / 4084 kts
35	1023 / > 1021.5 kts	1023 / > 4086 kts

Bit	GEO = 0	GEO = 1
36	GEO FLAG Bit (GEO = 0)	GEO FLAG Bit (GEO =1)
37	SIGN BIT FOR VERTICAL RATE (0=Up, 1=Down)	SIGN BIT FOR VERTICAL RATE (0=Up, 1=Down)
38	VERTICAL RATE (9 bits)	VERTICAL RATE (9 bits)
39	All zeros – no vertical rate information	All zeros – no vertical rate information
40	LSB = 64 feet/min	LSB = 64 feet/min
41	Value / Vertical Rate	Value / Vertical Rate
42	1 / 0 ft/min	1 / 0 ft/min
43	2 / 64 ft/min	2 / 64 ft/min
44	--- / ---	--- / ---
45	510 / 32576 ft/min	510 / 32576 ft/min
46	511 / > 32608 ft/min	511 / > 32608 ft/min
47	NIC SUPPLEMENT (§A.1.4.10.6)	NIC SUPPLEMENT (§A.1.4.10.6)
48	NAVIGATION ACCURACY CATEGORY FOR VELOCITY (NAC_V) (§A.1.4.5.5)	RESERVED (1 bit)
49		DIFFERENCE SIGN BIT (0 = Above Baro, 1 = Below Baro Alt)
50		GEOMETRIC HEIGHT DIFFERENCE FROM BARO ALT (7 bits) (§A.1.4.5.7) (All zeros = no info) (LSB = 25 feet)
51	SURVEILLANCE INTEGRITY LEVEL	Value / Vertical Rate
52	(§A.1.4.10.9)	1 / 0 ft
53	RESERVED	2 / 25 ft
54	RESERVED	--- / ---
55	TRUE / MAGNETIC HEADING (0 = True, 1 = Magnetic)	126 / 3125 ft
56	RESERVED	127 / > 3137.5 ft

Purpose: To provide velocity information for aircraft that are not equipped with 1090 MHz ADS-B when the TIS-B service is based on high quality surveillance data.

Subtype Coding:

Code	Velocity	Type
3	Airspeed, Heading	Normal
4		Supersonic

Note: *The "Vertical Rate" and "Geometric Height Difference From Barometric" fields for surface aircraft do not need to be processed by TIS-B receivers*

Figure A-17: TIS-B Coarse Airborne Position Message

Bit	Field
1	IMF (§A.2.4.5.1)
2	SURVEILLANCE STATUS
3	
4	MSB
5	SERVICE VOLUME ID (SVID)
6	
7	LSB
8	MSB
9	
10	
11	
12	
13	PRESSURE ALTITUDE
14	
15	
16	
17	
18	
19	LSB
20	GROUND TRACK STATUS (1 = Valid, 0 = Invalid)
21	
22	
23	GROUND TRACK ANGLE
24	(§A.2.4.5.5)
25	
26	
27	
28	GROUND SPEED
29	(§A.2.4.5.6)
30	
31	
32	CPR FORMAT (F) (0 = Even, 1 = Odd)
33	MSB
34	
35	
36	
37	
38	CPR ENCODED LATITUDE
39	(§A.2.4.5.7)
40	
41	
42	
43	
44	LSB
45	MSB
46	
47	
48	
49	
50	CPR ENCODED LONGITUDE
51	(§A.2.4.5.7)
52	
53	
54	
55	
56	LSB

Purpose: To provide airborne position information for aircraft that are not equipped with 1090 MHz ADS-B when TIS-B service is based on moderate quality surveillance data.

A.3 ADS-B Rebroadcast Service – Formats and Coding

A.3.1 Introduction

The TIS-B MASPS, RTCA/DO-286B defines an "ADS-B Rebroadcast Service", as a "Fundamental TIS-B Service," that may be provided. The Messages of the ADS-B Rebroadcast Service are not transmitted by aircraft, but by ADS-B ground stations.

Notes:

1. *This section of Appendix A defines the formats and coding for an ADS-B Rebroadcast Service (see the TIS-B MASPS, RTCA/DO-286B, §1.4.1) based on the same 112-bit 1090 MHz Extended Squitter signal transmission that is used for DF=17 ADS-B Messages on 1090 MHz.*
2. *The ADS-B Rebroadcast Service complements the operation of ADS-B and the Fundamental TIS-B Service (see the TIS-B MASPS, RTCA/DO-286B, §1.4.1) by providing ground-to-air rebroadcast of ADS-B data about aircraft that are not equipped for 1090 MHz Extended Squitter ADS-B, but are equipped with an alternate form of ADS-B (e.g., Universal Access Transceiver (UAT)). The basis for the ADS-B Rebroadcast transmission is the ADS-B Report received at the ground station using a receiver compatible with the alternate ADS-B data link.*
3. *The ADS-B Rebroadcast ground-to-air transmissions use the same signal formats as the DF=17 1090 MHz Extended Squitter ADS-B and can therefore be accepted by a 1090 MHz ADS-B Receiving Subsystem, with the exceptions identified in the following sections.*

A.3.2 ADS-B Rebroadcast Format Definition

ADS-B Rebroadcast information is transmitted using the 112-bit Mode S DF=18 format specified in Figure A-11.

A.3.3 Control Field Allocation

The content of the DF=18 transmission is defined by the value of the Control Field (CF). As specified in Table A-29, ADS-B Rebroadcasts (i.e., ADS-R) transmissions **shall** use CF=6 and ADS-R Management information transmissions (i.e., defining ADS-R Service Volume and service availability) **shall** use CF=4.

A.3.4 ADS-B Rebroadcast Surveillance Message Definitions

The Rebroadcast of ADS-B information on the 1090 MHz Extended Squitter data link is accomplished by utilizing the same ADS-B Message formats defined in Figure A-1 through Figure A-10, with the exception of the need to transmit an indication to the 1090 MHz Receiving Subsystem as to the type of identity associated with the aircraft data being reported in the ADS-B Rebroadcast Message. This identification is performed using the ICAO/Mode A Flag (IMF), which was previously discussed in §A.2.4.1.1 for the TIS-B transmissions.

The insertion of this one bit into the ADS-B Messages identified below allows the ADS-B Receiving Subsystem to interpret the Address Field (AF) in the following manner:

IMF = 0 indicates that the ADS-B Rebroadcast data is identified by an ICAO 24-bit Address

IMF = 1 indicates that the ADS-B Rebroadcast data is identified by an anonymous 24-bit Address

A.3.4.1 Rebroadcast Airborne Position Message

The ME Field of the Rebroadcast Airborne Position Message will be formatted as specified in section §A.1.4.2 and Figure A-1, except that ME bit 8 is redefined to be the ICAO/Mode A Flag (IMF).

A.3.4.2 Rebroadcast Surface Position Message

The ME Field of the Rebroadcast Surface Position Message will be formatted as specified in section §A.1.4.3 and Figure A-2, except that ME bit 21 is redefined to be the ICAO/Mode A Flag (IMF).

A.3.4.3 Rebroadcast Aircraft Identification and Category Message

The ME Field of the Rebroadcast Aircraft Identification and Category Message will be formatted exactly as specified in section §A.1.4.4 and Figure A-4.

Note: *Any Rebroadcast Aircraft Identification and Category Message does not contain the IMF bit since aircraft using an anonymous 24-bit address will not provide identity and category information.*

A.3.4.4 Rebroadcast Airborne Velocity Message

The ME Field of the Rebroadcast Airborne Velocity Messages will be formatted as specified in section §A.1.4.5.1 and Figure A-5 for Subtype 1 & 2 Messages, and in section §A.1.4.5.2 and Figure A-6 for Subtype 3 & 4 Messages, except that ME bit 9 is redefined to be the ICAO/Mode A Flag (IMF).

A.3.4.5 Rebroadcast Extended Squitter Aircraft Status Message

The ME Field of the Rebroadcast Extended Squitter Aircraft Status Message will be formatted as specified in section §A.1.4.8 and Figure A-8, except that ME bit 56 is redefined to be the ICAO/Mode A Flag (IMF).

A.3.4.6 Rebroadcast Target State and Status Message

The ME Field of the Rebroadcast Target State and Status Message will be formatted as specified in section §A.1.4.9 and Figure A-9, except that ME bit 51 is redefined to be the ICAO/Mode A Flag (IMF).

A.3.4.7 Rebroadcast Aircraft Operational Status Message

The ME Field of the Rebroadcast Aircraft Operational Status Message will be formatted as specified in section §A.1.4.10 and Figure A-10, except that ME bit 56 is redefined to be the ICAO/Mode A Flag (IMF).

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APPENDIX B

ACRONYMS & DEFINITION OF TERMS

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B Acronyms and Definition of Terms

B.1 Acronyms

1090ES – 1090 MHz Extended Squitter

AC - Advisory Circular

ACARS - Aircraft Communications, Addressing and Reporting System

ACAS – Airborne Collision Avoidance System

ADS - Automatic Dependent Surveillance

ADS-B - Automatic Dependent Surveillance-Broadcast

ADS-R – ADS-B – Rebroadcast Service

AGC – Automatic Gain Control

AGL - Above Ground Level

AIP - Aviation Information Publications

A/V - Aircraft/Vehicle

ARINC - ARINC Incorporated (formally Aeronautical Radio Incorporated)

ASIC - Application Specific Integrated Circuit

ATCRBS - Air Traffic Control Radar Beacon System

ATC - Air Traffic Control

ATM - Air Traffic Management

ATS - Air Traffic Services

ATIS - Automatic Terminal Information Service

AWB – Angular Weighted Binary

BCD - Binary Coded Decimal

BDS - Comm-B Data Selector

BER - Bit Error Rate

BNR - Binary Numbers

BW - Bandwidth

C/A - Coarse Acquisition

CC - Clock Correction

CDI - Course Deviation Indicator

CF - Course-to-Fix

CPA - Closest Point of Approach

CNS - Communications, Navigation and Surveillance

CDTI - Cockpit Display of Traffic Information

CRC - Cyclic Redundancy Check

CTAS - Center TRACON Automation System

CW - Continuous Wave

DME - Distance Measuring Equipment

DMTL - Dynamic Minimum Trigger Level

DOD - U.S. Department of Defense

DOP - Dilution Of Precision

DP - Datum Point

dps - Degrees Per Second

DR - Dead Reckoning

DRWP - Departure End of Runway Waypoint (associated with a departure procedure)

EC - Ephemeris Correction

ECEF - Earth Centered Earth Fixed

EFIS - Electronic Flight Instruments System

EL - Glidepath Angle (approach path elevation angle)

ELT - Emergency Locating Transmitter

EPU - Estimated Position Uncertainty

ERP - Effective Radiated Power

ETA - Estimated Time of Arrival

EUROCAE - European Organization for Civil Aviation Equipment

FAA - Federal Aviation Administration

FAF - Final Approach Fix

FAR - Federal Aviation Regulation

FAS - Final Approach Segment

FAWP - Final Approach Waypoint

FD - Fault Detection

FDE - Fault Detection and Exclusion

FIS-B - Flight Information Services-Broadcast

FTE - Flight Technical Error

FMS - Flight Management System

fpm - Feet Per Minute

FRUIT – False Replies Unsynchronized In Time

FSD - Full Scale Deflection

FSS - Flight Service Station

FTE - Flight Technical Error

GFM – General Formatter/Manager

GICB - Ground Initiated Comm-B

GL - Ground Level

GNSS - Global Navigation Satellite System

GPS - Global Positioning System

{HEX} – Hexadecimal

HF - High Frequency

HIRF - High Intensity Radiation Fields

Hz - Hertz

IAC - Instantaneous Airborne Count

IAS - Indicated Airspeed

ICAO - International Civil Aviation Organization

IFR - Instrument Flight Rules

ILS - Instrument Landing System

IMC - Instrument Meteorological Conditions

INS - Inertial Navigation System

I/O - Input and/or Output

ITC - In-Trail Climb

ITD - In-Trail Decent

ITU - International Telecommunication Union

JAA - Joint Aviation Authorities

JAR - Joint Aviation Requirements

L1 - 1575.42 MHz (a navigation frequency associated with GPS)

LAAS - Local Area Augmentation System

LADGPS - Landing Area Differential GPS

lb. - pounds

LORAN - Long Range Navigation

LSB - Least Significant Bit

LSR - Least Squares Residual

MASPS - Minimum Aviation System Performance Standards

MFD - Multi-Functional Display

MHz - Megahertz

MOPS - Minimum Operational Performance Standards

MTBF - Mean Time Between Failure

MS - Mode Status

MSL - Minimum Signal Level

MTL - Minimum Trigger Level

MTTR - Mean-Time-To-Restore

MTR - Military Training Route

NAC_{BARO} – Navigation Accuracy Category - Barometric

NAC_{P} – Navigation Accuracy Category – Position

NAC_{V} – Navigation Accuracy Category – Velocity

NAD-83 - North American Datum 1983

NAS - U.S. National Airspace System

NAV - Navigation

NAVAID - Navigation Aid

NIC – Navigation Integrity Category

NIC_{BARO} – Navigation Integrity Category – Barometric

NM - Nautical Mile

NOTAM - Notice to Airmen

NTD – Non-Mode S Transponder Device

NUC_P - Navigation Uncertainty Category - Position

NUC_R - Navigation Uncertainty Category - Velocity

OBS - Omni Bearing Selector

OC - On Condition

PIREP - Pilot Report

PPM - Pulse Position Modulation

PRC - Pseudo range Correction

PRM - Precision Runway Monitoring

P_r - Probability of Receipt

PSR - Primary Surveillance Radar

PUC - Position Uncertainty Category

RA - Resolution Advisory

RAIM - Receiver Autonomous Integrity Monitoring

R_C – Radius of Containment

RCP - Required Communication Performance

RF - Radio Frequency

RMP - Required Monitoring Performance

rms - Root Mean Square

RNP - Required Navigation Performance

RSP - Required System Performance

rss - Root-Sum-Square

RVR - Runway Visual Range

RVSM - Reduced Vertical Separation Minimum

SA or S/A - Selective Availability

SAE - Standard Aerospace Equipment

SAR - Search And Rescue

SARPS - Standards and Recommended Practices

SID - Standard Instrument Departure

SIL – Surveillance Integrity Level

SNR - Signal-to-Noise Ratio

sps - symbols per second

SPS - Standard Positioning Service

SSR - Secondary Surveillance Radar

STAR - Standard Terminal Arrival Routes

SUA - Special Use Airspace

SV - State Vector

TA - Traffic Advisory

TAS - True Airspeed

TCAS - Traffic Alert and Collision Avoidance System

TCP - Trajectory Change Point

TERPS - Terminal Instrument Procedures

TIS - Traffic Information Service

TIS-B - Traffic Information Service-Broadcast

TMA - Terminal Maneuvering Area

TRS – Transmission Rate Subfield

TSD - Traffic Situation Display (see also CDTI)

TSE - Total System Error

TSO - Technical Standards Order

TTG - Time to Go

U.S. - United States

UTC - Coordinated Universal Time

VFR - Visual Flight Rules

VMC - Visual Meteorological Conditions

VNAV - Vertical Navigation

VUL - Vertical Uncertainty Level

VHF - Very High Frequency

VNAV - Vertical Navigation

VOR - VHF Omnidirectional Range

VUC - Velocity Uncertainty Category

WAAS - Wide Area Augmentation System

WGS-84 - World Geodetic System 1984

Xmt - Transmit

B.2 Definition of Terms

Accuracy - A measure of the difference between the A/V position reported in the ADS-B message field as compared to the true position. Accuracy is usually defined in statistical terms of either 1) a mean (bias) and a variation about the mean as defined by the standard deviation (sigma) or a root mean square (rms) value from the mean. The values given in this document are in terms of the two-sigma variation from an assumed zero mean error.

Acquisition Squitter – A short message (format DF=11) that Mode S Transponders transmit automatically, without needing to be interrogated by a radar, to announce the own-ship aircraft's presence to nearby TCAS-equipped aircraft. (Also see Extended Squitter.)

Active Waypoint - A waypoint to or from which navigational guidance is being provided. For a parallel offset, the active waypoint may or may not be at the same geographical position as the parent waypoint. When not in the parallel offset mode (operating on the parent route), the active and parent waypoints are at the same geographical position.

ADS-B (Automatic Dependent Surveillance – Broadcast) – A system for airborne or surface aircraft, or other surface vehicles operating within the airport surface movement area, that periodically transmits a State Vector and other information.

ADS-B Broadcast and Receive Equipment - Equipment that can transmit and receive ADS-B messages. Defined as Class A equipment.

ADS-B Broadcast Only Equipment - Equipment that can transmit but not receive ADS-B messages. Includes transponder based equipment that is capable of receiving 1030 MHz SSR interrogations. Defined as Class B equipment.

ADS-B Message - A modulated packet of formatted data which conveys information used in the development of ADS-B reports.

ADS-B Only Transmitter - An ADS-B transmitter that is not part of a Mode S transponder.

ADS-B Rebroadcast Service – This is one of the Services provided by the TIS-B system (see the TIS-B MASPS, RTCA/DO-286A, §1.4.2). The ADS-B Rebroadcast Service is a TIS-B Service in which ground stations Rebroadcast on one data link (e.g., 1090 MHz Extended Squitter as described in these MOPS) ADS-B Messages that were originally transmitted by an aircraft or vehicle on another data link (e.g., the Universal Access Transceiver, UAT).

ADS-B Receiver or 1090 MHz Receiver - An ADS-B receiver that is not a TCAS 1090 MHz receiver.

ADS-B Report - Specific Information provided by the ADS-B user participant subsystem to external applications. Reports contain identification, state vector, and status/intent information. Elements of the ADS-B Report that are used and the frequency with which they must be updated will vary by application. The portions of an ADS-B Report that are provided will vary by the capabilities of the transmitting participant.

ADS-B Subsystem - The set of avionics or equipment that performs ADS-B functionality in an aircraft or for ground-based, non-aircraft, participants.

ADS-B System - A collection of ADS-B subsystems wherein ADS-B messages are broadcast and received by appropriately equipped participant subsystems. Capabilities of participant subsystems will vary based upon class of equipage.

Advisory - An annunciation that is generated when crew awareness is required and subsequent crew action may be required; the associated color is unique but not red or amber/yellow. (Source: Advisory Circular AC 25 - 11).

Aircraft Address - The term "address" is used to indicate the information field in an ADS-B message that identifies the ADS-B unit that issued the message. The address provides a continent means by which ADS-B receiving units — or end applications — can sort messages received from multiple issuing units.

Aircraft/Vehicle (A/V) - Either 1) a machine or service capable of atmospheric flight, or 2) a vehicle on the airport surface movement area. In addition to A/Vs, ADS-B equipage may be extended to temporarily uncharted obstacles (i.e., obstacles not identified by a current NOTAM).

Air Mass - Air mass data includes barometric altitude and air speed.

Alert Zone - In the Free Flight environment, each aircraft will be surrounded by two zones, a protected zone and an alert zone. The alert zone is used to indicate a condition where intervention may be necessary. The size of the alert zone is determined by aircraft speed, performance, and by CNS/ATM capabilities.

Along-Track Distance - The distance along the desired track from the waypoint to the perpendicular line from the desired track to the aircraft.

Altitude, Barometric – See *barometric altitude*.

Altitude, Geometric – See *geometric height*.

Applications - Specific use of systems that address particular user requirements. For the case of ADS-B, applications are defined in terms of specific operational scenarios.

Barometric Altitude - Geopotential altitude in the earth's atmosphere above mean standard sea level pressure datum surface, measured by a pressure (barometric) altimeter.

Barometric Altitude Error - For a given true barometric pressure, P_o, the error is the difference between the transmitted pressure altitude and the altitude determined using a standard temperature and pressure model with P_o.

Call Sign - The term "aircraft call sign" means the radiotelephony call sign assigned to an aircraft for voice communications purposes. (This term is sometimes used interchangeably with "flight identification" or "flight ID"). For general aviation aircraft, the aircraft call sign is normally its national registration number; for airline and commuter aircraft, it is usually comprised of the company name and flight number (and therefore not linked to a particular airframe); and for the military, it usually consists of numbers and code words with special significance for the operation being conducted.

Caution - An annunciation that is generated when immediate crew awareness is required and subsequent crew action will be required; the associated color is amber/yellow. (Source: Advisory Circular AC25 - 11).

Closest Point of Approach (CPA) - The minimum horizontal distance between two aircraft during a close proximity encounter, a.k.a. miss distance.

Cockpit Display of Traffic Information (CDTI) - A function which provides the pilot/flight-crew with surveillance information about other aircraft, including their position. The information may be presented on a dedicated multi-function display (MFD), or be processed for presentation on existing cockpit flight displays. Traffic information for the CDTI function may be obtained from one or multiple sources (including ADS-B, TCAS, and TIS) and it may be used for a variety of purposes. Requirements for CDTI information will be based on intended use of the data (i.e., application).

Collision Avoidance - An unplanned maneuver to avoid a collision.

Conflict - Any situation involving two or more aircraft, or an aircraft and an airspace, or an aircraft and ground terrain, in which the applicable separation minima may be violated.

Conflict Detection - The process of projecting an aircraft’s trajectory to determine whether it is probable that the applicable separation minimum will not be maintained between the aircraft and either 1, another aircraft or vehicle, 2, a given airspace, or 3, ground terrain. The level of uncertainty in the projection is reduced with increased knowledge about the situation, including aircraft capabilities, flight plan, short term intent information, etc.

Conflict Management - Process of detecting and resolving conflicts.

Conflict Probe - The flight paths are projected to determine if the minimum required separation will be violated. If the minima are not [projected to be] violated, a brief preventive instruction will be issued to maintain separation. If the projection shows the minimum required separation will be violated, the conflict resolution software suggests an appropriate maneuver.

Conflict Resolution - The process of identifying a maneuver or set of maneuvers that, when followed, do not cause a conflict or reduce the likelihood of conflict between an aircraft and either 1, another aircraft or vehicle, 2, a given airspace, or 3, ground terrain. Maneuvers may be given to multiple aircraft to fully resolve a conflict.

Conformance - The condition established when the surveillance report of an aircraft’s position at some time “t” (established by the Automated Tracking function) is within the conformance region constructed around that aircraft at its nominal position at time “t”, according to the agreed upon trajectory.

Cooperative Separation - This concept envisions a transfer of responsibility for aircraft separation from ground based systems to the air-crew of appropriately equipped aircraft, for a specific separation function such as In-trail merging or separation management of close proximity encounters. It is cooperative in the sense that ground-based ATC is involved in the handover process, and in the sense that all involved aircraft must be appropriately equipped, e.g., with RNAV and ADS-B capability, to perform such functions.

Cross-link - A cross-link is a special purpose data transmission mechanism for exchanging data between two aircraft—a two-way addressed data link. For example, the TCAS II system uses a cross-link with another TCAS II to coordinate resolution advisories that are generated. A cross-link may also be used to exchange other information that is not of a general broadcast nature, such as intent information.

Desired Course - Can be either 1) True - A predetermined desired course direction to be followed (measured in degrees from true north), or 2) Magnetic - A predetermined desired course direction to be followed (measured in degrees from local magnetic north).

Effective Update Interval - The time interval between successful message receipt with at least 98% probability of successful reception. For example, if ADS-B messages are sent at one second intervals in signal-to-noise conditions with 75% probability of success per transmission, then the probability of obtaining at least one message in three tries is $= 1. - (0.25)^{3} \sim 98.4\%$. Thus the effective update interval for this case = 1 sec x 3 = 3 sec.

Effective Update Rate - The reciprocal of effective update interval, e.g. rate = 1/3 ~ 0.33 Hz for the example above.

En Route - A phase of navigation covering operations between departure and termination phases. En route phase of navigation has two subcategories: en route domestic/continental and en route oceanic.

Event Driven Messages - Those messages that are transmitted from Mode S Transponder-Based ADS-B Transmitting Subsystems in response to a certain event: namely, the loading of the event-driven register, Mode S Transponder register 0A {HEX}. This is according to the "event-driven protocol" described in the Mode S Transponder MOPS (RTCA/DO-181D, §2.2.23.1.2). When these message formats are transmitted from Non-Transponder-Based devices, they might still be called event-driven messages, but a better term would be "*On-Condition*" messages. (See On-Condition.)

Extended Squitter – A long message (format DF=17) that Mode S Transponders transmit automatically, without needing to be interrogated by a radar, to announce the won-ship aircraft's presence to nearby ADS-B equipped aircraft. (Also see Acquisition Squitter.)

Final Approach Fix (FAF) - A point in space used to indicate the position at which an aircraft on a standard approach should be stabilized with appropriate guidance being supplied for the Final Approach Segment. (Source: FAA)

Flight Technical Error (FTE) - The accuracy with which the aircraft is controlled as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include blunder errors.

Free Flight - Free Flight is a safe and efficient flight operating capability under IFR in which the operators have the freedom to select their path and speed in real time.[TF3, Oct. 1995].

FRUIT - False Replies [from transponders] Unsynchronized In Time. See Garble, Non-synchronous.

Garble, Non-synchronous - Interfering reception of two or more replies. Interfering replies received from a transponder that is being interrogated by some other source is called FRUIT.

Geometric Dilution of Position (GDOP) - The ratio of position error of a multi-lateration system. More precisely, it is the ratio of the standard deviation of the position error to the standard deviation of the measurement errors, assuming all measurement errors are statistically independent and have a zero mean and the same standard distribution. GDOP is the measure of the "goodness" of the geometry of the multi-lateration sources as seen by the observer; a low GDOP is desirable, a high GDOP undesirable. (See also PDOP, HDOP and VDOP.)

Geometric height - The minimum altitude above or below a plane tangent to the earth's ellipsoid as defined by WGS84.

Geometric height error - Geometric height error is the error between the true geometric height and the transmitted geometric height.

Global Navigation Satellite System (GNSS) - GNSS is a world-wide position, velocity, and time determination system, that includes one or more satellite constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

Global Positioning System (GPS) - A space-based positioning, velocity and time system composed of space, control and user segments. The space segment, when fully operational, will be composed of 24 satellites in six orbital planes. The control segment consists of five monitor stations, three ground antennas and a master control station. The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.

GNSS Altitude (MSL) - The height of the aircraft (or of its GNSS antenna) above the *geoid*, which is the surface that represents mean sea level. The term *geoid,* as defined by the National Geodetic Survey's *Geodetic Glossary,* is the equipotential surface of the Earth's gravity field which best fits, in the least squares sense, mean sea level.

Graticule - A network of lines on a map representing geographic parallels and meridians.

Height Above Touchdown (HAT) - Specifically, the height above the Runway Intercept Waypoint. In using this term for airborne equipment specifications, care should be taken to define the point on the aircraft (GPS antenna, wheel height, center of mass) that applies.

Horizontal Dilution of Precision (HDOP) - The ratio of user-referenced horizontal position error to measurement error of a multi-lateration system. (See GDOP for a more detailed description.)

In-Trail Climb - In-trail climb (ITC) procedures enables trailing aircraft to climb to a more fuel-efficient or less turbulent altitude.

In-Trail Descent - In-trail descent (ITD) procedures enables trailing aircraft to descend to a more fuel-efficient or less turbulent altitude.

Interactive Participants - An ADS-B network member that is a supplier of information to the local ADS-B subsystem and a user of information output by the subsystem. Interactive participants receive messages and assemble reports specified for the respective equipage class.

Latency - The latency of an ADS-B transmission is the time period from the time of applicability of the aircraft/vehicle position ADS-B report until the transmission of that ADS-B report is completed.

Latency Compensation - High accuracy applications may correct for system latency introduced position errors using ADS-B time synchronized position and velocity information.

Latitude – In this document, “latitude” always means “WGS-84 geodetic latitude.” That is, the latitude of a point is the angle that a line that passes through that point, and that is normal to the WGS-84 ellipsoid, makes with the equatorial plane of that ellipsoid. North latitudes are positive, and south latitudes are negative.

Longitude – In this document, “longitude” always means “WGS-84 geodetic longitude.” That is, the longitude of a point is the angle between the plane of that point’s local geodetic meridian and the plane of the WGS-84 prime meridian (the meridian of Greenwich). East longitudes are positive, and west longitudes are negative.

Maximum Operating Range – The maximum range at which it is expected that the ADS-B Airborne System will provide the performance necessary to meet the ADS-B MASPS (RTCA/DO-242A) requirements.

Message – See ADS-B Message.

Mode S - A secondary surveillance radar (SSR) system that operates using addressed interrogations on 1030 MHz and transponder replies on 1090 MHz. Mode S supports a two-way data link and an ADS-B service known as Extended Squitter.

NAC_P – Navigation Accuracy Category for Position. Values of this parameter are based on values of Estimated Position Uncertainty (EPU), as defined in §2.1.2.13 of RTCA DO-242A.

NAC_V – Navigation Accuracy Category for Velocity. Values of this parameter are based on 95% bounds on the errors in reported velocity and are defined in §2.1.2.14 of RTCA DO-242A.

Navigation Mode - The navigation mode refers to the equipment operating to meet the requirements for a specific phase of flight. The navigation modes are: oceanic/remote, en route, terminal, non-precision approach, and precision approach. The oceanic/remote mode is optional; if it is not provided, the en route mode can be substituted for the oceanic mode.

Near Term - Near-term applications are defined as those that can be supported by an initial ADS-B implementation and that may be operationally feasible within the context of a current ATC system or the ATC systems of the near future.

NIC – Navigation Integrity Category. A parameter that specifies an integrity containment radius, R_C.

Non-Transponder-Based Implementation - An ADS-B Transmitting Subsystem that is not part of a Mode S transponder.

Normal Maneuver - Any maneuvers within the aircraft's approved flight-loads envelope that does not exceed 60 degrees angle of bank, or results in an abrupt change in the aircraft's attitude or accelerations. Abrupt changes in accelerations are those which exceed the values shown below. *Note that g = acceleration of gravity = 9.8 m/s²*.

Horizontal Acceleration	Vertical Acceleration	Total Jerk
0.58 g	0.5 g	0.25 g/s

NUC – Navigation Uncertainty Category. Uncertainty categories for the state vector navigation variables are characterized by a NUC data set provided in the ADS-B sending system. The NUC includes both position and velocity uncertainties.

On-Condition Messages – Those messages that are transmitted from 1090 MHz ADS-B Transmitting Subsystems for the duration of an operational condition. When a Mode S Transponder is used as the ADS-B Transmitting Subsystem, *On-Condition* messages are when Register $0A_{16}$ is loaded with the message contents. (See *Event-Driven Messages*.) Various *On-Condition* messages are described in subparagraphs under §2.2.3.2.7 of these MOPS, and include the Target State and Status Message (TYPE=29, Subtype=0,

§2.2.3.2.7.1), the Aircraft Operational Status Message (TYPE=31, Subtype=0 for airborne, Subtype=1 for surface, §2.2.3.2.7.2), and the 1090ES Aircraft Status Message (TYPE=28, §2.2.3.2.7.8), which contains both the Emergency/Priority Status Message (Subtype=1), and the TCAS Resolution Advisory (RA) Broadcast Message (Subtype=2).

Passing Maneuvers - Procedures whereby pilots use: 1, onboard display of traffic to identify an aircraft they wish to pass; 2, traffic display and weather radar to establish a clear path for the maneuver; and 3, voice communication with controllers to positively identify traffic to be passed, state intentions and report initiation and completion maneuver.

Planned Primary Means - Use of ADS-B for Planned Primary Means will be possible for selected airspace operations based upon predictable conditions, e.g., GNSS constellation, type of operation, and extent of ADS-B equipage for participating aircraft. That is, ADS-B will be available as a primary means of surveillance for particular periods of time in particular geographical regions for approved operations.

Phase of Flight - The phases of flight are defined as follows:

1. Oceanic/Remote - Radio updating is not viable due to either very limited navigation aid coverage or no navigation aid coverage.

2. En route/Domestic - Aircraft sequences above 15,500 feet while not actively flying a SID, or is above 15,500 and sequences the last way point of a SID, or the phase of flight is Oceanic and radio updating is viable.

3. Terminal - Aircraft sequences below 15,000 feet; or when the aircraft is in Approach and exceeds 3,000 feet above arrival airport elevation if there is no missed approach holding point, or the missed approach holding point is sequenced; or the aircraft is in Takeoff and exceeds 3,000 feet above departure airport elevation if no SID exist in active flight plan, or the last way point of the SID is sequenced below 15,500.

4. Approach - The first way point on the active approach or approach transition is sequenced, or the aircraft sequences below 2,000 feet above arrival airport elevation. Approach flight phase will not be active when a VFR approach is in the active flight plan.

Position Uncertainty Category (PUC) - The position uncertainty category (PUC) is needed for surveillance applications to determine whether the reported position has an acceptable level of position uncertainty. The category is based on the aircraft's estimate of position uncertainty (EPU), as defined in 3.1.2 of the RNP MASPS[9]

Primary Means of Navigation - The airborne navigation equipment that meets the requirements of radio navigation for the intended phase of flight (route to be flown). These requirements include satisfying the necessary level of accuracy, integrity, continuity, and availability for a particular area, route, procedure, or operation. Examples of systems which provide a primary means of navigation include:

a. VOR for domestic en route, terminal, and non precision approach where it is available;

b. VOR/DME for domestic en route above flight level 240, terminal, and non precision approach where it is available;

c. OMEGA for Oceanic Operation;

d. INS for Oceanic Operation;

Protected Zone - In the Free Flight environment, each aircraft will be surrounded by two zones, a protected zone and an alert zone. The protected zone must remain sterile to assure separation. It can be envisioned as a distance-based "hockey puck" with radius equal to half the horizontal separation minimum and vertical extent equal to ± half the vertical separation minimum. The size of the protected zone is a direct reflection of the position determination accuracy.

Received Update Rate - The sustained rate at which periodic ADS-B messages are successfully received, at a specified probability of reception.

Reliability - The probability of performing a specified function without failure under given conditions for a specified period of time.

Resolution - The smallest increment reported in an ADS-B message field. The representation of the least significant bit in an ADS-B message field.

Report - See ADS-B Report.

Required Navigation Performance (RNP) - A measure of the navigation system performance within a defined airspace, route, or procedure, including the operating parameters of the navigation's systems used within that airspace. (Source: Adapted from the ICAO Separation Panel).

Seamless - A "chock-to-chock" continuous and common view of the surveillance situation from the perspective of all users.

Sole Means of Navigation - An approved navigation system for a given operation or phase of flight that must allow the aircraft to meet, for the operation or phase of flight, all four navigation system performance requirements: accuracy, integrity, availability, and continuity of service.

Squitter – A message transmitted from a Mode S Transponder or other ADS-B transmission device that is broadcast automatically, without the need for the transponder to be interrogated by a radar. (Also see Acquisition Squitter and Extended Squitter.)

Station-keeping - Station-keeping provides the capability for a pilot to maintain an aircraft's position relative to the designated aircraft. For example, an aircraft taxiing behind another aircraft can be cleared to follow and maintain separation on a lead aircraft. Station-keeping can be used to maintain a given (or variable) separation. An aircraft that is equipped with an ADS-B receiver could be cleared to follow an FMS or GNSS equipped aircraft on a GNSS/FMS/RNP approach to an airport. An aircraft doing station-keeping would be required to have, as a minimum, some type of CDTI.

State Vector - An aircraft or vehicle's current kinematic state.

Supplemental Means of Navigation - An approved navigation system that can be used in controlled airspace of the NAS in conjunction with a sole means of navigation.

Tactical Parameters - Tactical information may be used to enhance the performance of designated applications. System designs should be flexible enough to support tactical parameters; however, it is not required to provide the parameters in all implementations.

TCAS Implementation - ADS-B transmit and receive capability implemented as part of a TCAS installation (1090 MHz transmit and receive).

Terminal Area - A general term used to describe airspace in which approach control service or airport traffic control service is provided.

Total System Error (TSE) - Generic: The root-sum-square of the navigation source error, airborne component error, display error and flight technical error. Specific: The root-sum-square of the position fixing error, display error, course selection error and flight technical error.

Track Angle - Instantaneous angle measured from either true or magnetic north to the aircraft's track.

Transmission Rate - The sustained rate at which periodic ADS-B messages are transmitted.

Transponder Based Implementation - An ADS-B transmitter implemented as part of, or added capability to, a Mode S transponder.

Traffic Situation Display (TSD) - A TSD is a cockpit device that provides graphical information on proximate traffic as well as having a processing capability that identifies potential conflicts with other traffic or obstacles. The TSD may also have the capability to provide conflict resolutions.

Trajectory Change Point (TCP) - TCPs provide tactical information specifying space/time points at which the current trajectory of the vehicle will change. This change in vehicle trajectory could be in the form of a change in altitude (climb/descent), a change in heading, a change in airspeed (increase/decrease), or any combination thereof.

Velocity Uncertainty Category (VUC) - The velocity uncertainty category (VUC) is needed for surveillance applications to determine whether the reported velocity has an acceptable level of velocity uncertainty.

Vertical Profile - A line or curve, or series of connected lines and/or curves in the vertical plane, defining an ascending or descending flight path either emanating from or terminating at a specified waypoint and altitude, or connecting two or more specified waypoints and altitudes. In this sense, a curve may be defined by performance of the airplane relative to the airmass.

Warning - An annunciation that is generated when immediate recognition and corrective or compensatory action is required; the associated color is red. (Source: Advisory Circular AC25 - 11)

World Geodetic Survey (WGS) - A consistent set of parameters describing the size and shape of the earth, the positions of a network of points with respect to the center of mass of the earth, transformations from major geodetic datums, and the potential of the earth (usually in terms of harmonic coefficients).

World Geodetic System 1984 -- A set of quantities, developed by the U.S. Department of Defense for determining geometric and physical geodetic relationships on a global scale, based on a geocentric origin and a reference ellipsoid with semi-major axis 6378137 and flattening 1/298.257223563.

B.3 Illustrations of Geodetic Coordinate Definitions

B.3.1 Latitude, Longitude and Geodetic Height

Figure B-1 illustrates the definitions of the geodetic coordinates: latitude (ϕ), longitude (λ), and geodetic height (h).

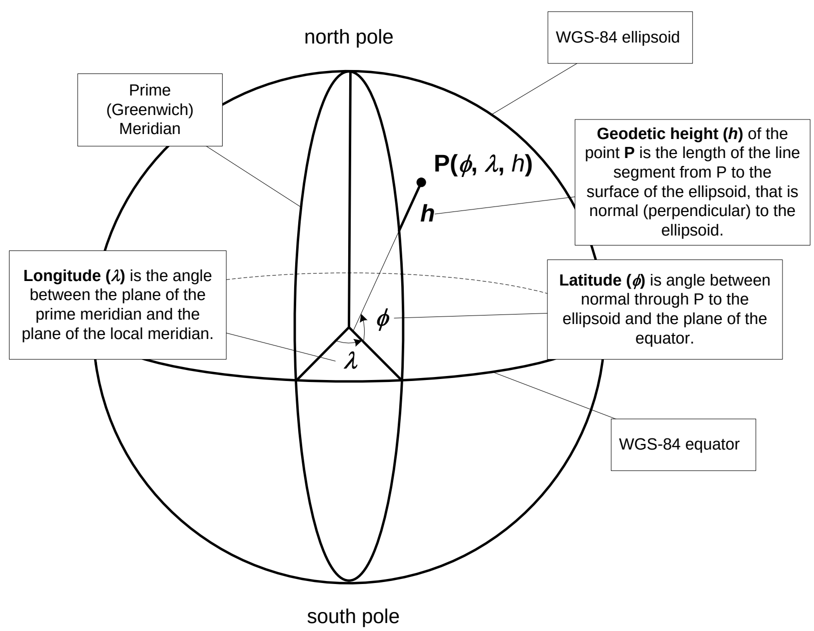

Figure B-1: **Geodetic Coordinate Definitions**

Figure B-2 illustrates the definition of latitude in more detail by showing the WGS-84 ellipsoid with a very exaggerated eccentricity.

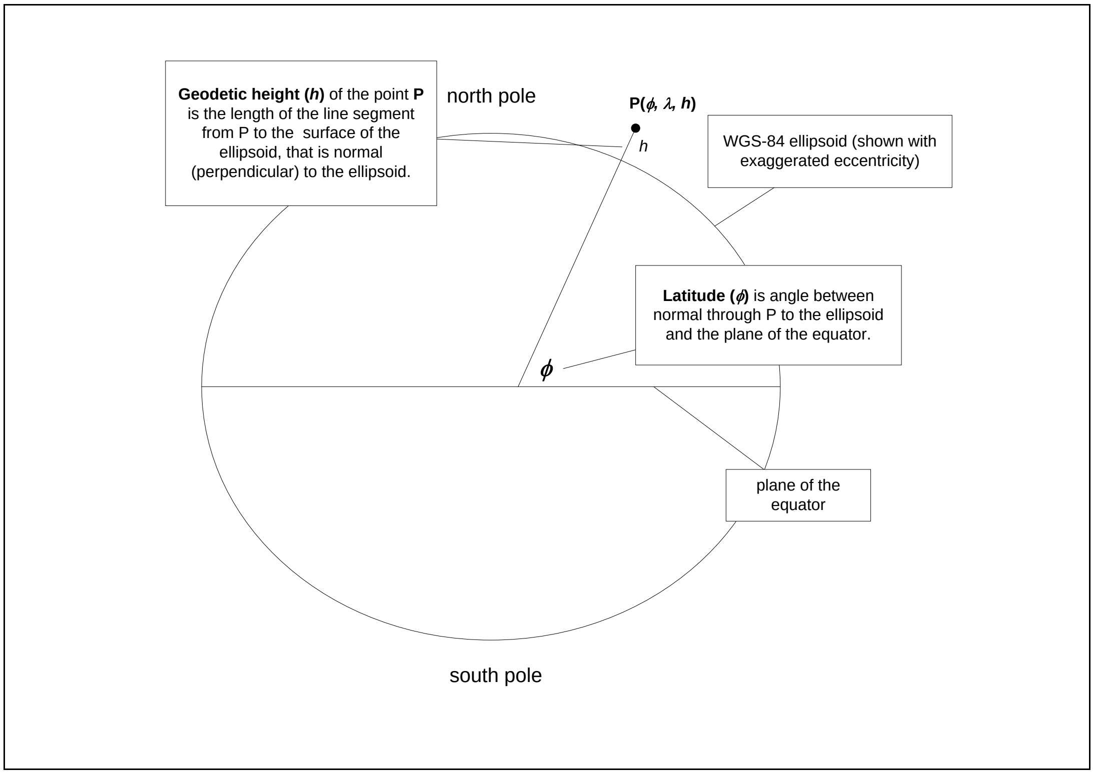

Figure B-2: **Latitude Definition**

B.3.2 Latitude and Longitude Representations

Latitude and longitude are angles, and so may be represented in various angular units of measure: radians, degrees, or circles. One important way of representing angles is as binary fractions of a circle ("angular weighted binary," or AWB). Many avionics position data sources use ARINC 429 data buses to deliver such angular parameters as latitude, longitude, and heading, and the binary ARINC 429 data words use the angular weighted binary notation for representing angles.

Figure B-3 illustrates how latitude and longitude are represented using radians, degrees, and binary fractions of a circle.

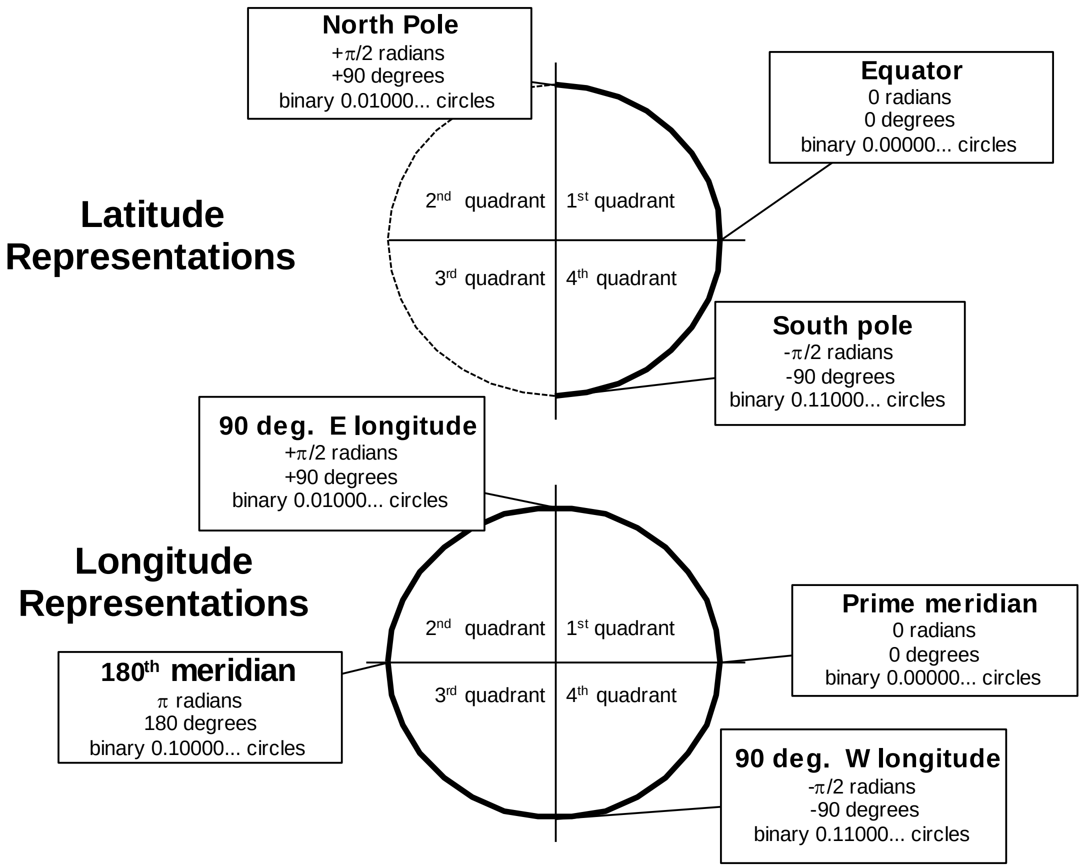

Figure B-3: Representations of Latitude and Longitude

Appendix C

Aircraft Antenna Characteristics

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C Aircraft Antenna Characteristics

C.1 Introduction

Transmissions and receptions of signals in the 1090 MHz frequency band are affected significantly by aircraft antenna gain characteristics. Such effects are known to be significant in the performance of the existing ATCRBS, Mode S surveillance and collisions avoidance (TCAS/ACAS) systems. Similarly, aircraft antenna effects can be expected to be significant in the performance of Extended Squitter ADS-B.

To support surveillance from the ground, ideally an aircraft antenna would provide coverage that is omnidirectional in azimuth, and that maintains signal strength when an aircraft banks and/or pitches. Furthermore the physical antenna should be small to minimize drag. Practical antennas installed on aircraft differ from the ideal in several ways. The most obvious difference is that a single antenna provides good coverage over just one of the two hemispheres. A bottom mounted antenna provides coverage in downward directions, and a top mounted antenna provides coverage in upward directions, and both top and bottom antennas provide coverage horizontally. Primary applications of 1090 MHz Extended Squitter require full solid angle mutual observability. Operational performance for IFR applications must be provided in any geometry between any two aircraft. Unlike ground based surveillance, message exchanges are required between all aircraft within line of sight and within range for reception prescribed for each equipment type. Therefore the installed antenna performance must provide adequate coverage in the volume fully surrounding an airborne aircraft. It follows that there is a significant benefit in having a diversity installation consisting of both a top antenna and a bottom antenna.

Another departure from ideal performance is caused by the obstruction of signals by the tail of the aircraft, which affects top antenna performance. Typically a top antenna pattern will exhibit a reduction in gain in the aft direction. Because of the size of an aircraft tail relative to one wavelength (which is about 1 foot at 1090 MHz), the signal is not completely blocked by the tail, but instead it is made weaker by several dB. Signals in this direction may be still useful, depending on the range and other factors in the link power budget.

In addition to the tail, objects such as other antennas, propeller blades, engines, wheels, and flaps can also cause blockage of 1090 MHz signals. Furthermore it is possible for reflections from a wing or other flat surface on the aircraft to interfere constructively or destructively with the signal and cause additional fluctuations in signal strength.

Considerations such as these have prompted a viewpoint that the entire aircraft should be considered as part of the antenna. In the descriptions and data that follow, this point of view is adopted. Antenna gain is considered to be a characterization of the installed antenna, including all effects of the aircraft.

Given the operational requirement for mutual observability, the installed antenna(s) must support adequate received power at the maximum range for the each equipment type. At these ranges the practical observation angles between operationally relevant aircraft for A1S/A1 equipment are limited to the values of ±10 degrees. At the greatest ADS B range for A3 the angles are limited to the same values even with extreme altitude differences which must be supported. Mutual observation at high angle slant ranges must be continuous with adequate received power to maintain reception probability necessary to provide the Report update rates required at the current range. Antenna gain patterns change rapidly with increasing elevation angles from horizontal. Consequent degradation may by compensated by the improved range advantage in realistic geometric conditions producing high angular values (e.g., ±75 degrees). Antenna installation designs must maximize air to air surveillance functionality to be essentially free of operational holes.

Upper and lower antenna configurations and diversity techniques will typically be necessary to support applications intended for IFR airspace procedures. The following sections provide indications of the variations in coverage and link pattern performance expected for antenna locations and diversity systems.

C.2 Model Aircraft Antenna Pattern Measurements

A large set of antenna gain measurements is given in Reference C-1. These were made using 20:1 scale aircraft models. The measurements were made in an antenna test range. The model aircraft was installed on a movable mount that enabled testing in every direction. Measurements were made in 2 degree steps in both azimuth and elevation. The measurement techniques are described in the reference. Measurements were made for the following types of aircraft, and for several antenna locations on each aircraft, some top mounted and some bottom mounted.

Piper Cherokee
Shrike Commander
Cessna 150
Cessna 402B
Cessna Cardinal
Beech Baron
Beech B99
Twin Otter
Helio U10D
Gates Lear Jet
Grumman Gulfstream II

These include both high wing and low wing aircraft, single engine and twin engine aircraft, and small jet aircraft. The focus on General Aviation types of aircraft was intended to complement data that already existed for larger air carrier types. Photos in this reference show each of the aircraft models, and indicate the antenna locations that were tested. The measured patterns are given in the form of polar plots showing the three principal planes for each antenna on each aircraft. Similar model measurements were also made for several air carrier aircraft, namely,

Boeing 727
Boeing 737
Boeing 707
Boeing 747

as described in Reference C-2.

C.3 Analysis of Aircraft Antenna Gain Measurements

The data given in Reference C-1 has been analyzed in several different ways, as described in Reference C-2. This report presents a different plotting format called the "Gain-Contour Plot", which has the advantage of showing the entire antenna pattern (in every direction) on one plot. The resulting plots reveal patterns that can be recognized as effects of obstruction and in some cases vertical lobing caused by reflection from a wing. These interpretations are described in the report.

Reference C-2 also presents a statistical analysis, which is useful in system design and performance assessments. Results are presented showing the probability of each possible value of antenna gain. Therefore, while recognizing that certain very low values of antenna gain exist, these results indicate how common these conditions are. Results are also presented showing the degradation in performance due to conditions of flaps down, wheels down, and banking.

Building on those analyses and results, Reference C-3 presents a set of antenna gain contour plots for a large number of aircraft-antenna combinations. The results are useful in that they extend the cases described in Ref. C-2, providing a much larger number of cases in which to observe the described effects.

Building further on the results in Reference C-2, an additional analysis is given in Reference C-4. The results provide a probability distribution of aircraft antenna gain for the entire set of aircraft, including all of the antenna locations tested (page 18). This curve, which is the cumulative probability distribution of antenna gain values, is useful in designing a system, in which it is important to allow for many different aircraft types and antenna locations. The application of this data to the system design of TCAS is the main subject of this report. The results presented in Ref. C-4 are given in two ways, one for aircraft having a single bottom mounted antenna, and the other for aircraft equipped with a diversity combination consisting of a top antenna and a bottom antenna. To characterize top-bottom diversity, this analysis assigns the antenna gain in a particular direction to be the larger of the two values (gain of the bottom antenna and gain of the top antenna).

An explicit mathematical model for aircraft antenna gain is given in the TLAT report (Ref. C-5). This is a stochastic model that is consistent with the frequency of occurrence of antenna-gain values in Ref. C-4, and includes a formula to characterize the effects of elevation angle for top and bottom antennas. This antenna-gain model was used for the performance assessments made in the TLAT Report (Ref. C-5).

In summary, the probability distribution of antenna gain values given in Ref. C-4 and C-5 is a useful characterization of aircraft antenna gain deviations caused by banking, obstructions, and reflections. It is the product of model measurements made on a number of aircraft, including both general aviation and air carrier types, and a number of possible antenna locations on each. This data was used in designing the air-to-air power budget for TCAS, and has been used for air-to-air and air-to-ground transmission and reception of Extended Squitter signals.

APPENDIX C REFERENCES

C-1. K. J. Keeping and J. C. Sureau, "Scale Model Pattern Measurements of Aircraft L-Band Beacon Antennas," M I T Lincoln Laboratory Project Report ATC-47, April 1975.

C-2. G. J. Schlieckert, "An Analysis of Aircraft L-Band Beacon Antenna Patterns," M I T Lincoln Laboratory Project Report ATC-37, Jan. 1975.

C-3. D. W. Mayweather, "Model aircraft L-Band Beacon Antenna Pattern Gain Maps," M I T Lincoln Laboratory Project Report ATC-44, May 1975.

C-4. W. H. Harman, "Effects of RF Power Deviations on BCAS Link Reliability," M I T Lincoln Laboratory Project Report ATC-76, June 1976.

C-5. *The ADS-B Technical Link Assessment Team (TLAT) – Technical Link Assessment Report,* March 2001, Appendix J.

APPENDIX D

1090 MHz ADS-B
GROUND ARCHITECTURE EXAMPLE

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D 1090 MHz ADS-B Ground Architecture Example

D.1 Introduction and Purpose

This appendix defines examples of ground architectures that can support (1) surveillance for ATC using Extended Squitter ADS-B reports and (2) Traffic Information Service Broadcast (TIS-B) on 1090 MHz.

ATC Surveillance

The FAA is interested in Extended Squitter as a means of surveillance of aircraft via ground stations. Surveillance of both airborne aircraft and aircraft on the airport surface are of interest. The FAA has been investigating ground architectures that would be appropriate for this purpose. The results are summarized in this appendix. An example 1090 ground architecture for high density airspace in a current radar environment is summarized in this appendix. As new information arises from programs such as Safe Flight 21 (including evaluation efforts in Ohio River Valley and Alaska Capstone), the FAA and the NAS users will collectively revise the architecture to refine the course of NAS modernization.

Note that the Traffic Information Service (TIS) capability is not included in the Extended Squitter ground station, since this service will be provided by conventional secondary radars with Mode S capability.

Traffic Information Service - Broadcast

Traffic Information Service - Broadcast (TIS-B) on 1090 MHz is a ground-to-aircraft broadcast service that provides "ADS-B like" surveillance transmissions for aircraft that are not equipped for 1090 MHz ADS-B. TIS-B makes non-equipped aircraft visible to an aircraft with an ADS-B receiver. The surveillance source for this ground-to-aircraft broadcast can be a rotating beam terminal or enroute radar. Other possible surveillance sources are enroute, terminal/approach radars and surface multilateration systems. Such multilateration systems provide a higher update rate and better surveillance accuracy than terminal or enroute radars.

TIS-B is considered to be an integral part of an ADS-B system since it is an important element in transition. If Extended Squitter surveillance is in use in a region of airspace, TIS-B can make all aircraft visible to a user with a 1090 MHz receiver even though not all aircraft are equipped for Extended Squitter.

D.2 ATC Surveillance

D.2.1 Avionics Equipage

In order to achieve a surveillance system that is based on Extended Squitter, it is necessary to define a transition strategy for integrating Extended Squitter into the existing system that will accommodate the mixed environment that will exist for many years during the transition from SSR to a possible full use of Extended Squitter. For this reason, the following avionics equipment must be accommodated:

1. Mode A/C transponder

2. Mode S transponder without Extended Squitter

3. Mode S transponder with Extended Squitter

4. Non-transponder Extended Squitter device.

D.2.2 Transition Issues

A number of issues must be addressed in this transition strategy. Significant issues include:

1. Potential loss of independence between surveillance, navigation and communication functions.

2. Validation (or at least a reasonableness test) of reported position until reliability of this data is established by experience.

3. Surveillance in a mixed ADS-B/SSR environment for ATC airborne and surface surveillance

4. Backup surveillance for loss of GNSS function for individual aircraft due to an equipment malfunction.

5. Backup surveillance for loss of GNSS function over an extended area due to interference effects on GNSS operation.

6. The ability to suppress the creation of tracks on ADS-B reports that contain intentionally incorrect position information (i.e., spoofers).

D.2.3 Ground surveillance of airborne aircraft

D.2.3.1 Surveillance techniques

D.2.3.1.1 Current technology

ATC surveillance of airborne aircraft is currently provided by narrow scanning beam SSR's often collocated with primary radars. SSR's intended for terminal surveillance have a maximum range of 60 to 100 NM and a scan interval of 4 to 6 seconds. En route coverage is provided by SSR's with a maximum range of 200 to 250 NM and a scan interval of 8 to 12 seconds.

Different capabilities exist for these SSR's. This includes Mode A/C only capability based on sliding window or monopulse azimuth processing. The newest SSR's have Mode S (and Mode A/C) capability with monopulse azimuth determination. Mode S interrogators are able to support the readout of aircraft developed information on identity, aircraft state and intent. This latter capability is referred to as enhanced surveillance.

D.2.3.1.2 End state surveillance using Extended Squitter

The Extended Squitter technique provides formats for airborne use that are optimized for ATC surveillance. These formats include position, velocity, ICAO address and aircraft call sign. Provision is made to report the quality of the reported surveillance data based upon the accuracy of the navigation source data.

As appropriate experience is gained and a transition is made to ADS-B, squitter receiving stations might be able to replace some current SSR's. Terminal area squitter stations would have ranges up to 100 NM. Squitter stations would provide coverage up to 250 NM in en route airspace and up to 300 NM as required in remote areas. The squitter stations would be capable of transmitting interrogations in order to obtain additional information from the transponder, such as intent and Mode A code.

While these stations would provide omni-directional coverage, in most cases this would be achieved with an antenna having six to twelve sectors. Operation with such an antenna requires the use of a receiver associated with each antenna sector, with a single transmitter that may be switched between the sectors as required. The use of multiple sectors will be required at high density environments for increased traffic capacity, since each receiver only has to cope with the traffic in one sector. Such an antenna will also be required at en route stations in order to achieve the antenna gain required for long range operation. For illustrative purposes, six-sector antennas are used in this appendix for ground system configuration examples employing multi-sector antennas.

D.2.3.2 Airspace considerations

The potential for transition of ATC surveillance to Extended Squitter depends on the type of airspace being covered. The most likely application of Extended Squitter will be in airspace that does not currently have secondary radar surveillance coverage. This could be in a remote area or low altitude coverage in any airspace.

It is unlikely that ADS-B will replace secondary radar surveillance in any high density airspace for the foreseeable future. A principal consideration is the need for independence between surveillance and navigation in such airspace. A second consideration is the vulnerability of satellite navigation sources to low level interference. Such an interference event could result in the loss of satellite navigation service over areas measured in tens of kilometers. Providing backup surveillance for large numbers of aircraft will significantly increase the cost of the ADS-B ground station to the point where ADS-B may not be a cost effective replacement for radar. ADS-B replacement of secondary radar in high density airspace will likely require the development of a robust satellite navigation source, or the use of an alternate navigation source such as an inertial platform as a backup.

D.2.3.3 Transition strategy

D.2.3.3.1 Validation

If necessary, position validation can be performed by a single station equipped with a multi-sector antenna. Range would be determined by direct interrogation of the transponder, while bearing would be determined by measuring the relative amplitude of the received signals in the antenna sectors. Aircraft equipped with a non transponder device would only be able to support bearing validation unless the ground system is equipped with multilateration capability (e.g., airport surface surveillance).

Analysis indicates that a six-sector antenna can provide a bearing accuracy of around 2 degrees. This should be accurate enough for a reasonableness test in low density airspace, but would not be sufficient for a terminal area.

Where provided for backup service, multilateration can be performed in the background mode for validated aircraft for periodic revalidation of position. When validation is performed by direct interrogation, a technique similar to TCAS hybrid surveillance could be implemented to revalidate aircraft that have flight paths in close proximity to other aircraft.

D.2.3.3.2 Backup

If necessary, backup surveillance could be provided in terminal environments using a time- difference of arrival multilateration technique. Multilateration will require the use of multiple receiving stations. This could be configured as a central station surrounded by three or more outrigger stations. In this configuration, the central station would be a full Extended Squitter ground station with transmit and receive capability and a multi-sector antenna. The outrigger stations would be simple receivers with omni-directional antennas. If the multilateration system is provided with sufficient capacity, multilateration could provide backup for single aircraft or area failures of GNSS functionality.

Where multilateration is not available, aircraft will need to be interrogated at the nominal scan interval. Backup surveillance for non-transponder devices would only be possible if multiple bearing measurements are available through overlapping ground station coverage.

D.2.3.3.3 Mixed equipage

Surveillance on Mode S aircraft that are not equipped with Extended Squitter can be performed using multilateration on the short squitter, or by direct interrogation.

Surveillance of Mode A/C only aircraft would require an active interrogation approach. The use of active interrogations (single or whisper shout depending upon the Mode A/C traffic density) would be used to elicit Mode A or C replies at a regular rate. In effect, the ground station operates like a TCAS unit, but with a lower interrogation rate and at higher effective radiated power due to its increased operating range. Since the majority of the aircraft in high density environments will be Mode S equipped, at most 8 whisper/shout levels should be needed for Mode A/C surveillance out to 60 to 100 NM. The central station could obtain range and a coarse bearing estimate from its multi-sector antenna. The position could be refined by use of multilateration data from the outriggers. The coarse position estimate would be very helpful in eliminating phantoms (position reports made up of replies from different aircraft). Side lobe suppression will be required to limit replies in the antenna side lobes.

D.2.3.4 Special considerations for precision runway monitoring

One surveillance application is the monitoring of aircraft on precision approaches. This is sometimes referred to as precision runway monitoring (PRM). Using current technology, aircraft navigate on the approach using ILS or MLS and are monitored by

SSR, sometimes operating at a higher scan rate than for normal ATC surveillance. Thus the navigation and monitoring techniques are completely independent.

Consideration is being given to use GNSS as the basis for future landing systems. If GNSS is used for this purpose, it is likely that some independent form of validation would be required for ADS-B surveillance data before it could also be used for PRM. Without independent validation, ADS-B for PRM would not be able to detect a blunder caused by a malfunction of the navigation equipment. Such a malfunction would result in both the air crew and the ground believing that the aircraft was on the correct approach, when in fact a deviation had occurred.

One example of a validation for PRM is the use of multilateration on the Extended Squitter transmission, as described earlier. This technique would provide the necessary independence of surveillance and navigation. Another example of independent validation of the ADS-B reports from aircraft is readout of the ADS-B message and comparison to the ground radar position when the airport is equipped with a Mode S interrogator.

Another application of ADS-B in PRM is to use CDTI and associated alert algorithms for monitoring parallel approaches. To support this air-to-air application of ADS-B, the current ground-based techniques should be adequate as monitoring responsibility rests primarily in the cockpit.

D.2.4 Surface surveillance

D.2.4.1 Surveillance techniques

D.2.4.1.1 Current technology

Current surveillance on the airport surface is provided by primary radar in the form of the Airport Surface Detection Equipment (ASDE). The ASDE provides reliable surveillance on all targets (regardless of equipage) but does not provide identity, which is useful for blunder detection and resolution. For this reason, techniques for providing aircraft identity using the aircraft transponder are being considered.

Surveillance on the airport surface requires that the positional error be small compared to the size of an aircraft in order to provide reliable correlation with the ASDE report. This rules out the use of direct range and azimuth measurement, or even range-range multilateration due to the tolerance in the transponder turnaround delay. For this reason SSR-based surface systems such as ASDE-X (first operational site planned for mid-2003) use time-difference of arrival multilateration, since it is based only on the difference in time of the receipt of an aircraft transmission at spatially diverse ground stations.

D.2.4.1.2 End state surveillance using Extended Squitter

The Extended Squitter design provides formats for use on the airport surface that are optimized for surface surveillance. These formats include position, velocity, ICAO address and aircraft call sign. The accuracy needed for surface surveillance can be supported by GNSS using local or wide area differential corrections.

D.2.4.2 Transition strategy

D.2.4.2.1 Validation

If necessary, validation of surface position reports can be performed using multilateration on the Extended Squitter or acquisition squitter transmission. Once validated, the ADS-B reports can be used for improved surveillance performance. Multilateration can be performed in the background mode for validated aircraft for periodic revalidation of position.

D.2.4.2.2 Backup

The background process of multilateration provides position and identity for short or long squitter reports that do not contain GNSS position information. A total loss of GNSS service would cause the surveillance system to revert to full multilateration operation. This would result in lower surveillance performance since the position accuracy and update rate will be somewhat degraded and the aircraft will no longer provide velocity information. However, surveillance could continue throughout the loss of GNSS service.

D.2.4.2.3 Mixed equipage

With multilateration, the only aircraft requirement for surveillance is a periodic transmission. All Mode S transponders (even those that do not support Extended Squitter) transmit a short squitter on an average of once per second. This is a high enough rate to support multilateration for surface surveillance.

Mode A/C transponders do not squitter, so provision would have to be made to elicit periodic replies if Mode A/C aircraft are to participate in surface surveillance during the transition period. One approach is to modify the transponders to generate a reply once per second. This may not be a feasible approach, since high equipment modification costs could lead operators to resist such a modification. A second approach may be used if only a small percentage of surface aircraft are Mode A/C equipped (i.e., most aircraft are Mode S equipped). This approach is based on the use of the whisper/shout technique used by TCAS to interrogate only a subset of the Mode A/C aircraft within range.

D.2.4.2.4 ASDE-X Surface Surveillance System

The previous sections (§D.2.4.2.2 and §D.2.4.2.3) provided a general strategy for addressing transition issues that can lead to an end-state surface surveillance system based on Extended Squitter. This section summarizes the high-level capabilities of an operational system in the National Airspace System, called ASDE-X, that can provide a smooth transition to end-state surface surveillance systems.

ASDE-X is a new generation surface surveillance system that is being deployed in 25 airports starting in mid-2003. It consists of the following four major system components:

1. A surface movement "primary" radar that is similar to ASDE, but operating in the X-Band frequency.

2. A Transponder-Based multilateration/ADS-B system that provides position and identification to all Transponder-equipped aircraft or vehicles. The remote Receive/Transmit (R/T) stations of the multilateration system can interrogate

Mode A/C Transponders using whisper-and-shout sequences to determine target position based on time-difference-of-arrival techniques. The remote R/T and Receive Only (R/O) stations of multilateration also process Extended Squitters to derive position and identification information.

3. An automation that combines all of the sensor reports (primary/secondary radars, multilateration, ADS-B Extended Squitter) into a single track.

4. New high bright color displays.

The surface multilateration system of the ASDE-X provides validation of 1090 MHz ADS-B data, as well as back-up in the event of GNSS failure. Since surface multilateration also uses a whisper/shout technique to interrogate Mode A/C aircraft, ASDE-X can provide surveillance in a mixed equipage environment (Mode A/C and Mode S). Additionally, ASDE-X is capable of detecting surface targets that are not equipped with any type of Transponder and those targets with malfunctioning Transponders.

The FAA also plans to upgrade the existing 34 ASDE-3 systems with multilateration and multi-sensor data fusion capabilities.

In the end-state when all aircraft are 1090 MHz ADS-B equipped, ASDE-X can serve as an operational platform for providing surface surveillance through its R/O or R/T stations.

D.2.5 Transition Strategy Summary

A strategy for transitioning from an SSR to an Extended Squitter environment has been defined. An example of a planned operational surface surveillance system, ASDE-X, is provided to illustrate the implementation of a transition strategy. The strategy makes use of the capabilities of those SSR transponders to support validation, backup and mixed equipage scenarios through direct range and bearing measurement and multilateration. Since the ADS-B message is contained in an SSR waveform, the same equipment that is needed for independent position measurement of the SSR transponders can also be used to receive the ADS-B squitters. Transition is greatly simplified by the integration of the ADS-B function with the Mode S transponder.

D.2.6 Ground Architecture for Air-Ground Surveillance

D.2.6.1 Introduction

D.2.6.1.1 Purpose

The previous sections described a possible transition strategy for ATC use of Extended Squitter. The capability of Extended Squitter ground receiving stations was defined in general operational terms. The purpose of this section is to provide more details on the architecture that might be used to provide Extended Squitter surveillance for ground ATC use.

D.2.6.1.2 Overview

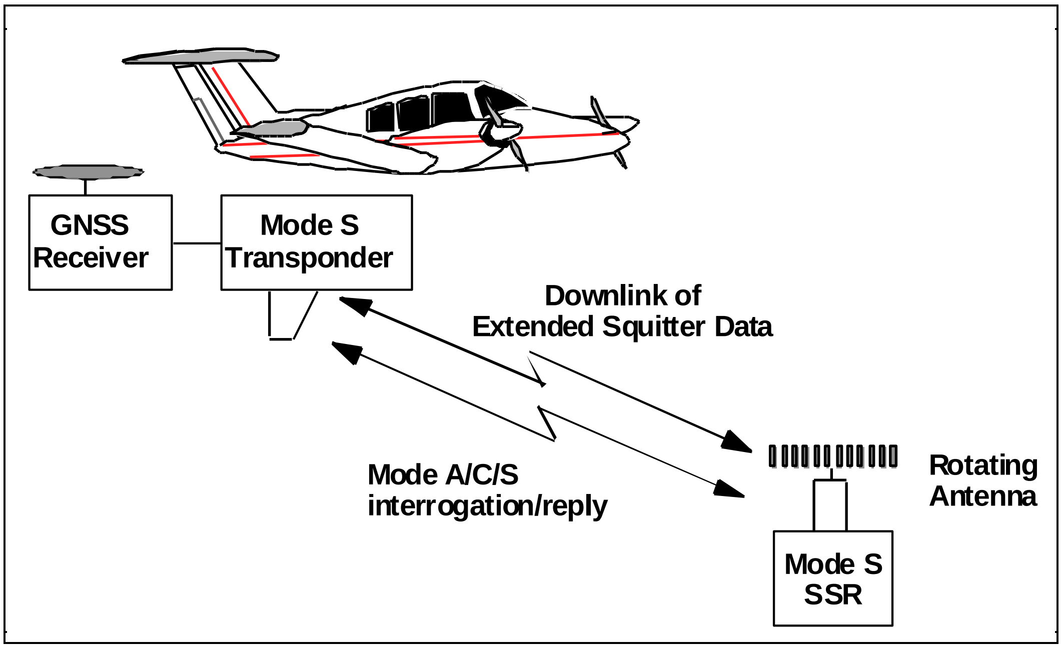
This section begins with a description of the currently implemented Mode S ground interrogators. This is relevant to Extended Squitter since ADS-B surveillance data can be obtained by a conventional Mode S interrogator via direct readout of the Mode S transponder. Such readout will likely be the initial technique for ATC use of ADS-B data. This is followed by a description of the architecture of increasingly more capable Extended Squitter ground stations.

D.2.6.1.3 Interface Considerations

Extended squitter ground stations will require the ability to interface with other ATC surveillance resources to generate a consolidated surveillance image. For this reason, these ground stations will be required to conform to an appropriate output interface standard (e.g., the internationally accepted Eurocontrol ASTERIX formats).

D.2.6.2 Mode S SSR Ground Station

A Mode S SSR normally operates with a scanning narrow beam antenna. This antenna is often mounted on the same pedestal as a co-located primary radar. Terminal Mode S SSRs operate with a scan time of 4 to 6 seconds and provide coverage out to 60 to 100 NM. En route Mode S SSRs operate with scan times of 8 to 12 seconds out to a range of 200 to 250 NM. A functional diagram of a Mode S SSR ground station is provided in Figure D-1.



<u>Figure D-1:</u> Mode S Secondary Surveillance Radar ground station providing surveillance of all Mode A/C/S aircraft in high density environments, as well as ADS-B surveillance (via enhanced surveillance), validation and spoofing resistance.

A Mode S SSR provides surveillance and data link service to Mode S equipped aircraft and surveillance service for Mode A/C equipped aircraft. Due to the use of monopulse, (a technique for determining the off-boresight angle of received replies) surveillance to a

Mode S aircraft is normally provided via a single interrogation per scan. Additional interrogations are scheduled each scan as needed to provide data link service.

One data link service supported by a Mode S SSR is the readout of transponder data registers that can be loaded by the aircraft to contain aircraft state, intent, weather data, etc. These registers can be accessed on demand by the Mode S SSR using the ground initiated Comm-B (GICB) protocol. This protocol is employed to provide the enhanced surveillance capability being mandated by States in the core area of central Europe.

Extended squitter information that is broadcast by a Mode S transponder is stored in the GICB registers. This means that ADS-B data is available on demand to a Mode S SSR. The ability to obtain GNSS position and velocity, as well as intent information, via a Mode S SSR can be an important benefit during a transition to ADS-B. In addition, ground readout of ADS-B data provides an opportunity to monitor the status of ADS-B implementation and, more importantly, the reliability of this data since it can be directly compared to the Mode S radar data.

D.2.6.3 Extended Squitter Ground Stations

D.2.6.3.1 Overview

An Extended Squitter ground station can be configured to provide different levels of performance as required.

A block diagram of the subsystems that could be included in a basic Extended Squitter transmit/receive ground station is shown in Figure D-2. The configuration shown is for a ground station with an omni-directional antenna. A ground system with a multi-sector antenna would require a receiver and reply processors for each antenna sector. A single transmitter would be used, with a switch to connect it to any antenna sector under control of the computer system.

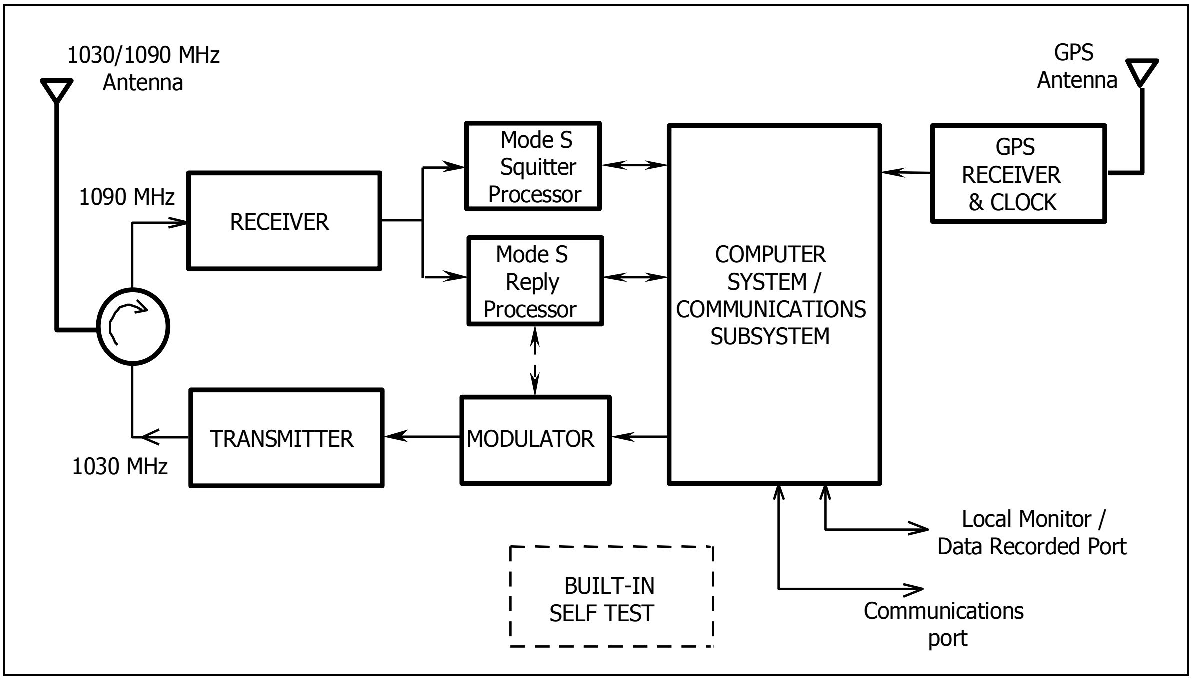


Figure D-2: Basic Extended Squitter System Block Diagram

D.2.6.3.2 Omni Antenna, Receive only

Capabilities: The simplest ground station only has the ability to passively receive Extended Squitter ADS-B reports. It operates with an omni directional antenna.

Intended Use: This configuration is expected to be used in low density or remote airspace not currently within ATC surveillance coverage.

A block diagram of this configuration is presented in Figure D-3.

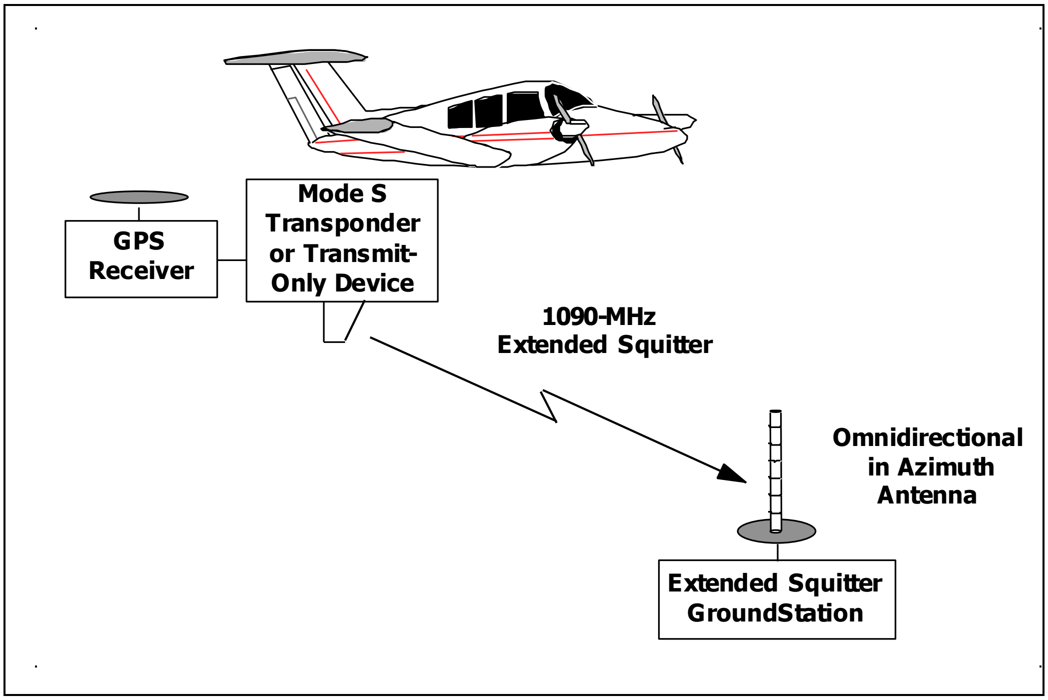


Figure D-3: **Simple receive-only Extended Squitter ground station configuration providing ADS-B surveillance.**

D.2.6.3.3 Omni Antenna, Receive only, Angle of Arrival Capability

Capabilities: This configuration provides the same reception capability as above, but it is augmented with a simple angle-of-arrival capability in order to obtain an approximate estimate of aircraft azimuth. This ground station configuration can provide azimuth validation on ADS-B equipped aircraft in low density airspace. Azimuth accuracy for such an antenna has been measured to be approximately 8 degrees, one sigma.

Validation: The angle-of-arrival validation capability enables the ground station to provide approximate validation of the ADS-B azimuth through direct comparison of the actively measured azimuth with the azimuth calculated from the ADS-B position report. In cases where overlapping coverage exists for this type of ground station, approximate aircraft positions can be developed using azimuth triangulation from the ground stations. This system allows for independent validation of ADS-B position reports.

Intended Use: The approximate position location provided by this configuration would make it suitable only for use in low density airspace.

A block diagram of this configuration is presented in Figure D-4. Note that multiple stations of this type that have overlapping coverage could perform azimuth triangulation.

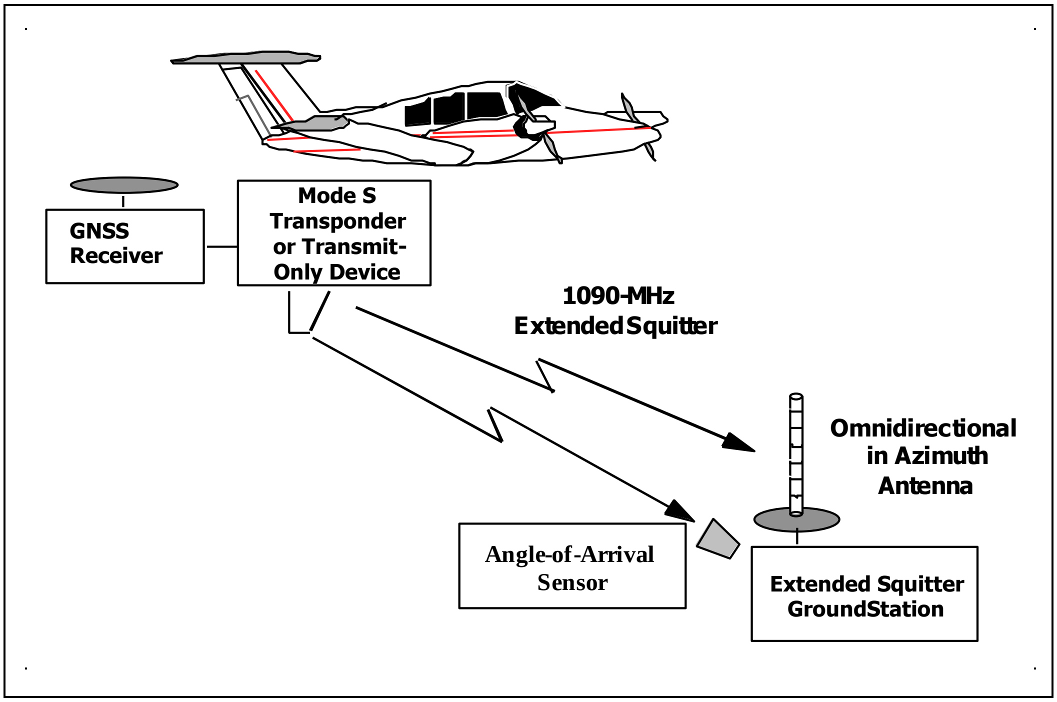


Figure D-4: Receive only Extended Squitter ground station with angle-of-arrival sensor configuration providing ADS-B surveillance, azimuth verification and spoofing resistance.

D.2.6.3.4 Six-Sector Antenna, Receive/Transmit

Capabilities: This configuration provides the same reception capabilities as the preceding configuration. In addition, it is equipped with a six-sector antenna, with one receiver per antenna beam and a single transmitter that may be switched to any beam as required. The use of the six-sector antenna allows operation into higher density than is possible with an omni antenna, since each receiver has to cope only with the squitters and Mode A/C replies received from a single antenna beam. An analysis of side lobe structure and traffic distribution indicates that such an antenna can be expected to provide a capacity 2.5 times the capacity of a ground station using an omni-directional antenna.

Validation and Fall-Back Surveillance: In addition to increased capacity, the six-sector antenna enables this ground station to provide a higher level of validation than the omni directional configuration. This is due to the ability of the six-sector antenna to provide azimuth measurement to an accuracy of 2-3 degrees using a simple amplitude monopulse processor. This coarse azimuth capability together with measured range (for a transponder implementation of Extended Squitter) can also be used to provide fall-back surveillance in the event of the loss of the navigation input for ADS-B. Fall-back surveillance refers to a lower performance form of surveillance that can be used during an outage of the principal surveillance system.

Mode S and Mode A/C Surveillance: The six-sector antenna enables this ground station configuration to provide improved surveillance on Mode S and Mode A/C equipped aircraft compared to the previous configuration.

Intended Use: This configuration is expected to be used in low to medium density en route airspace where a fall-back azimuth accuracy of 2-3 degrees may be operationally acceptable. Antennas with a greater number of sectors may be used to achieve higher capacity or improved azimuth measurement accuracy as required.

A block diagram of this configuration is presented in Figure D-5.

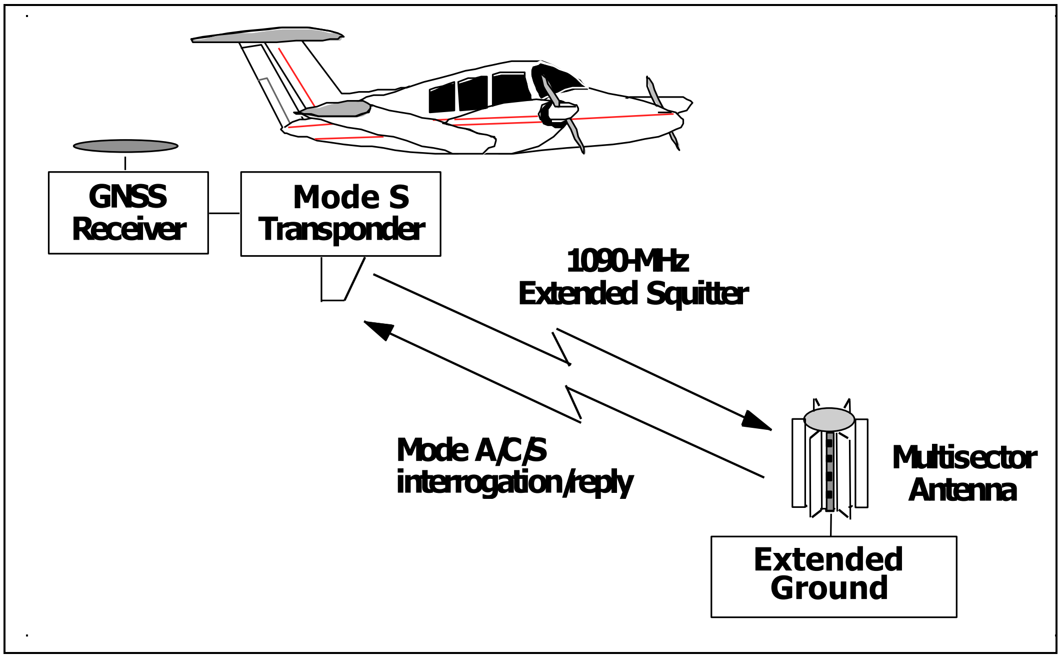


Figure D-5: Extended squitter ground station providing ADS-B surveillance, position validation, spoofing resistance, coarse surveillance of all Mode A/C/S aircraft and fall-back surveillance for ADS-B aircraft.

D.2.6.3.5 Multilateration Augmentation

Capabilities: This configuration is equipped with a number of receiving sites for the purpose of providing a time-difference of arrival multilateration capability. Multilateration augmentation may be added to any combination of the ground station configurations listed in §D.2.6.3 provided that three or more sites are located in view of target aircraft in the surveillance volume. Multilateration stations can be very simple, consisting of a 1090 MHz receiver, a reply processor, a means to accomplish accurate time stamping, and a communications modem. The physical size would be small, about the size of an SSR transponder. However, intersite communications would be required and 3 or more sites would have to be in view of a particular aircraft in order to obtain a multilateration solution.

Backup Surveillance: Depending on the geometry of the ground stations, multilateration position accuracy can equal or exceed that of an SSR. With this level of position accuracy, backup surveillance is possible. Backup surveillance refers to an alternative surveillance capability that can be used during an outage of the principal surveillance system that provides equivalent performance to the principle system.

Mode S and Mode A/C Surveillance: Mode S and Mode A/C surveillance capability can also be provided via active interrogation. The coarse position information provided by the six-sector antenna would be very useful in eliminating false targets that could otherwise result from performing multilateration on non-discrete Mode A Code replies.

Intended Use: The level of capability provided by this configuration would be appropriate for use in a terminal area.

A block diagram showing multilateration augmentation to a representative mix of ground station types providing primary and backup surveillance is presented in Figure D-6.

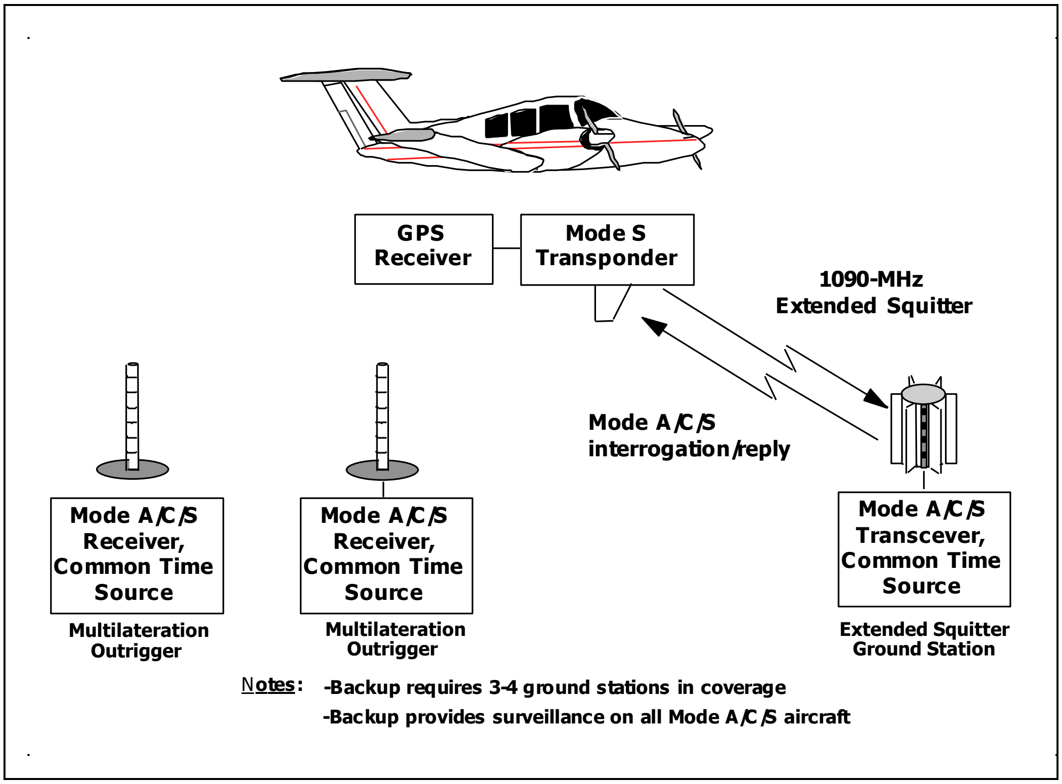


Figure D-6: Extended squitter ground station providing ADS-B surveillance, position validation, spoofing resistance, accurate surveillance of all Mode A/C/S aircraft and backup surveillance for ADS-B aircraft.

D.2.7 Ground Architecture for Surface Surveillance

D.2.7.1 Overview

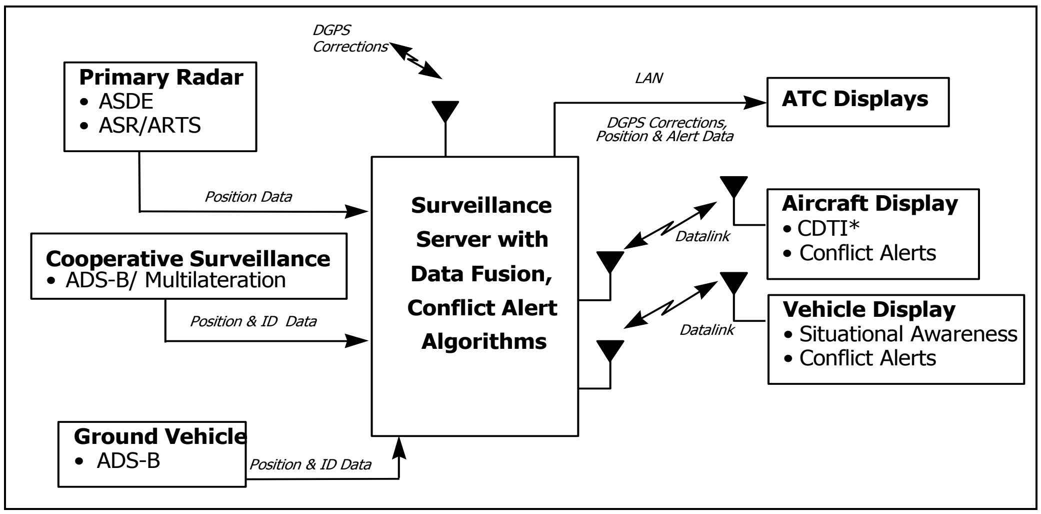
The purpose of this section is to describe the ground architecture that may be used for surface surveillance using Extended Squitter. As indicated above, transition and validation requirements will require the use of multilateration is support of surface surveillance. In addition, inputs from air-ground surveillance devices will also be required to monitor arriving aircraft

D.2.7.2 Extended Squitter Surface Ground System

Extended squitter ground stations for surface surveillance can be 1090 MHz receive only or may have 1030 MHz transmit capability in order to (optionally) manage surface squitter rates. These stations would use omni or single sector beam antennas as appropriate to cover the airport maneuvering area.

D.2.7.3 Candidate Ground Architecture

A candidate ground architecture for surface surveillance is shown in Figure D-7. This architecture features a surveillance server with data fusion capability to provide a surveillance picture based on the combined resources of ADS-B, multilateration, ASDE and the airport surveillance radar (ASR). This surveillance information is used to support a conflict alert algorithm. The surveillance and conflict alert results are provided to ground ATC. Provision is also made to data link alerts to the cockpit.



<u>Figure D-7:</u> Ground architecture for surface surveillance using ADS-B, multilateration and radar.

D.2.8 Integration with Other Radars and Automation Systems

D.2.8.1 Overview

With the introduction of ADS-B, the surveillance architecture will consist of a mix of primary and secondary air surveillance radars, one or more of the ADS-B ground station options described earlier in this Appendix and surface surveillance sensors including multilateration and ASDE. The sensors represent a mix in several respects:

- several different primary and secondary models,
- airport and en route equipage each support several different combinations of the primary and secondary models,
- surveillance installations interface with several different automation systems.

A few areas of CONUS, as well as parts of Alaska and Hawaii, currently have coverage gaps that may be filled with ADS-B ground stations, most likely with some degree of overlap. Most other areas currently have primary and secondary radars that provide substantial multiple coverage overlaps. The implementation of ADS-B ground stations in these areas will increase the basic coverage as well as the number of overlaps. Aircraft transponder equipage currently varies and it may well vary in the future with the ADS-B equipage options being considered.

Given this substantial mix and the growth toward free flight, made possible with ADS-B, there is an underlying need for a flexible integration scheme that can exploit the improved surveillance track database to produce unified tracks. That is, the sum of the track data available on a target from multiple surveillance sensors (radars and ADS-B) and from neighboring installations can be fused to provide a unified track on each target with much higher accuracy for ATC and ATM purposes. The FAA has been investigating methods that can fuse data from multiple and varied sensors toward this end goal.

D.2.8.2 The Need for Fusion

The need for sensor data fusion is predicated on several related key factors. They include:

- the surveillance sensor mixes encountered in the US and Internationally, particularly in European airspace,
- the absolute imperative to maintain safety as aircraft with mixed equipage share the same airspace will not allow reduced safe spacing requirements with current automation mosaicing techniques,
- the potential to reduce cost by reducing numbers of surveillance sensors may be enabled by fusing tracks from the remaining overlapping sensors,
- fused ground based surveillance from all sensor types supports a seamless gate-to-gate view of aircraft and surface vehicle surveillance which will support future automation and procedural alternatives,
- fused data will provide a source of information to support an ADS-B related product known as Traffic Information Service – Broadcast (TIS-B),
- supporting ATC and ATM in a Free Flight Environment requires improved surveillance performance in both air-air and air-ground modes, and
- efficiency in operations made possible by improved surveillance performance may lead to reduced separation minimums and reduced controller workload

D.2.8.3 Architecture Considerations

Surveillance and Automation teams within the FAA are currently investigating several technical issues that must be considered in selecting an effective and affordable fusion architecture approach. Consideration must also be given to hardware and software implementations that can be introduced as part of a larger transition in the NAS modernization process. Conceptually, each automation end point will be supported by one or more surveillance servers and a surveillance hub. Together they will provide the necessary interface to process and integrate data, which can be synchronous or asynchronous and can be displaced in time due to sensor locations. Data formats will have to be upgraded to incorporate longer data messages per target, preserve sensor data accuracy and event time and introduce new message content such as pilot intent. Key technical considerations include:

- the number and type of sensors and automation systems which are to be served,
- the interface data format (ASTERIX is the primary candidate),
- the flexibility for compensating sensor bias (registration) errors since these are usually the limiting factor in fusion,
- the selection of data combining techniques , that is the combining of data reports before fused track files are formed versus the fusing of individual sensor track files versus a hybrid combination of both methods,
- adaptability to sensor failures,
- communication requirements in terms of data link bandwidth,
- processor sizing and placement,
- current and projected state-of-the-art in fusion,
- the establishment of requirements to be applied to the surveillance data fusion system.

Figure D-8 illustrates an example of the many sites and types of equipage that would introduce target data to a surveillance hub and surveillance servers that implement fusion and provide a unified target database to automation.

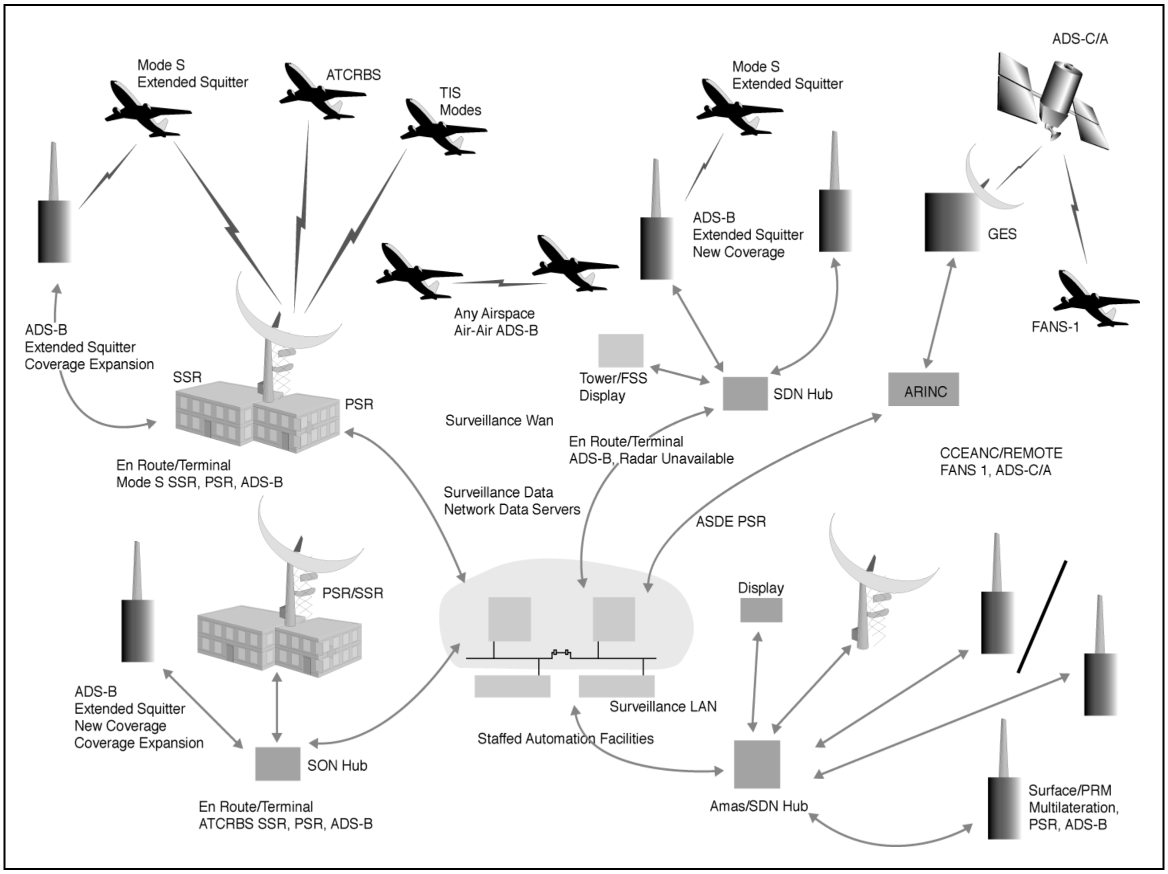


Figure D-8: Conceptual architecture for implementing surveillance fusion of multi-sensor / multi-site target reports

D.2.9 ATC Surveillance Summary

The Extended Squitter system provides a wide range of options for aircraft surveillance.

For surveillance of airborne aircraft, these options range from simple, low cost, ADS-B receive-only ground stations, to a six-sector configuration with multilateration that can provide ADS-B service plus surveillance of Mode A/C/S aircraft suitable for use in a terminal area. In the highest density airspace, the option exists for the use of Mode S Secondary Surveillance Radars that will support the surveillance of all Transponder-equipped aircraft in addition to readout of ADS-B data.

For surface surveillance, these options include ADS-B only, or ADS-B in combination with multilateration to support transition and validation activities.

D.3 Traffic Information Service Broadcast (TIS-B)

D.3.1 Overview

The formats and protocols required for avionics implementing TIS-B on 1090 MHz are specified in the body of these MOPS and in Appendix A. Ground processing for TIS-B on 1090 MHz must implement these same formats and compatible algorithms to interoperate with airborne equipment.

Specific requirements for the ground processing component of TIS-B are contained in the TIS-B MASPS. The TIS-B MASPS contain requirements for TIS-B in a link independent manner. The purpose of this section of Appendix D is to provide additional guidance on implementing ground processing for TIS-B service on 1090 MHz.

D.3.2 Ground Determination of Extended Squitter Equipage

The normal mode of TIS-B operation on 1090 MHz is to transmit traffic information only for targets that are not equipped with Extended Squitter. It is therefore necessary for TIS-B ground processing to determine which aircraft are Extended Squitter equipped.

Mode S transponders are equipped to provide a data link capability report in response to an interrogation from a Mode S ground radar. This data link report contains a bit flag to indicate if the transponder is equipped for Extended Squitter. However, this bit flag is not a reliable indicator of actual Extended Squitter operation. The bit flag is a static indication of the capability of the transponder support for Extended Squitter formats and protocols. It would not reflect the loss of extended quitter operation due to a malfunction of the transponder or to the navigation input.

The recommended technique for determining active Extended Squitter operation is to monitor 1090 MHz for Extended Squitter reception in an omni directional fashion. The most convenient way to implement this monitoring is to equip the 1090 MHz TIS-B ground stations to receive as well as transmit. This approach will also provide Extended Squitter determination for aircraft equipped with non-transponder devices.

D.3.3 Ground Radar Data Considerations

Wherever possible, the ground radar data used as the basis for TIS-B service should be based upon Mode S surveillance. The availability of ground surveillance data identified with the aircraft 24-bit address for Mode S equipped aircraft significantly enhances the correlation of ground surveillance data with received Extended Squitters. If an ATCRBS radar is used as the basis for TIS-B service, correlation between the ground radar data and the received Extended Squitters must be based only on position and altitude since Mode A code is not provided by any of the ADS-B systems.

D.3.4 TIS-B Format Selection

Two types of formats are defined for TIS-B on 1090 MHz:

1. Fine Formats

The fine TIS-B formats are similar to those used for Extended Squitter ADS-B operation. These formats are intended for use with surveillance data that is the same quality as that used for ADS-B. Examples of such data quality are surveillance inputs obtained by monitoring other ADS-B links, or a ground-based multilateration system.

The following fine TIS-B format types are defined:

Airborne Position
Airborne Velocity
Surface Position
Identification and Category

2. Coarse Format

The coarse format combines both position and velocity data into a single message. It is intended for use with surveillance data sources that are not accurate enough to warrant the use of the fine formats. The principal example is surveillance data derived from a scanning beam ground radar.

D.3.5 Ground Architecture

D.3.5.1 Overview

Because of the limited range and geometry of a single ground station, a network of ground transmitting stations will be required. Each station will have associated with it two types of coverage. One is the radio coverage of the transmitted signal. The radio coverage volume is the airspace that can be usefully reached by signal from the ground station. The other type of coverage is the service coverage. This is the geometric scope of responsibility that the ground station assumes for the TIS-B broadcast. The service coverage is, by definition, a subset of the radio coverage.

The TIS-B service area could be composed of a number of hexagonal cells. Each cell defines the area of service for the TIS-B transmitter located in the center of that cell. Overlap (or buffer zone) at cell boundaries only needs to be large enough to ensure continuity of service across the cell boundary. A minimum service overlap between adjacent cells is desirable in order to eliminate unnecessary duplicate TIS-B transmissions. Since TIS-B aircraft position reports are expected to be reasonably accurate in order to provide useful service, a buffer zone of 2 NM is assumed at cell boundaries.

A description of a typical TIS-B cell is presented in Figure D-9.

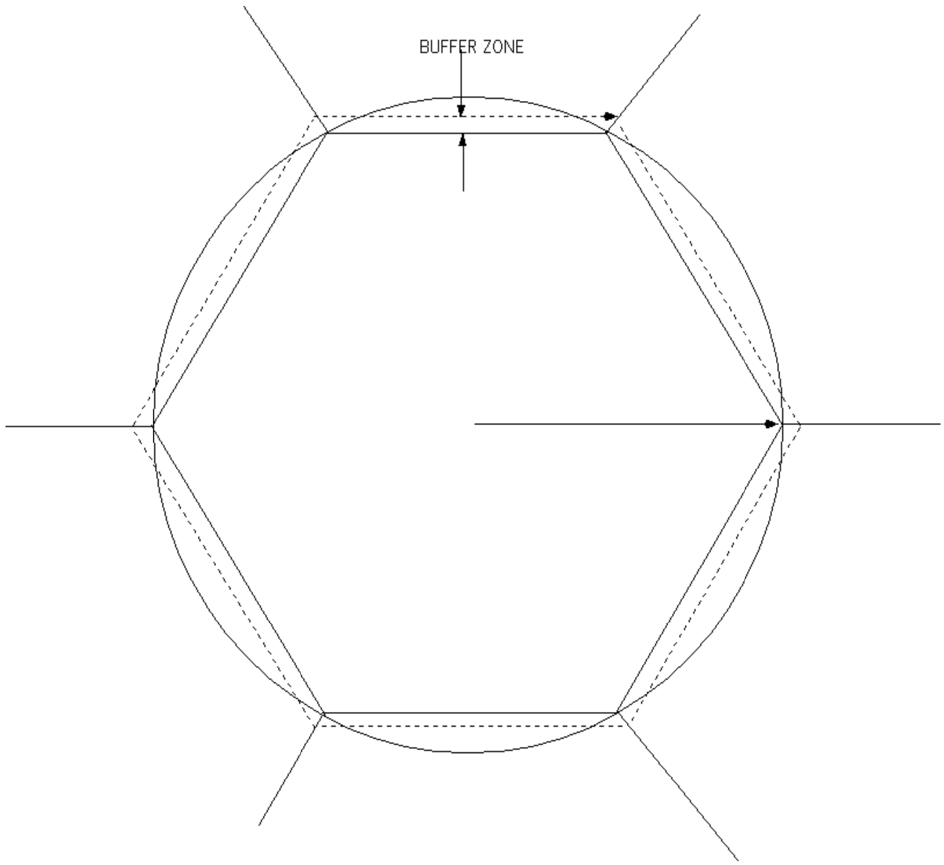


Figure D-9: TIS-B Cell Characteristics

D.3.5.2 TIS-B Cell Size Considerations

The cell size has an important role in determining TIS-B operating characteristics. A Smaller cell size is desirable for the following reasons:

1. A reduced maximum transmission range increases the probability of squitter reception.
2. A smaller cell contains fewer aircraft. This lowers the cell transmission rate and thus reduces the hot spot effect.
3. Due to earth curvature effects, a shorter operating range results in better low altitude coverage.

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Appendix E

Air-to-Air Range as Limited by Power

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E Air-to-Air Range as Limited by Power

The requirements for transmitter power and receiver sensitivity are different for the different avionics classes. These requirements, given in §2.2, can be summarized as follows.

Table E-1: Summary of Transmitter and Receiver Requirements

Avionics Class	**Transmitter Power** (dBm at antenna)	**MTL** (dBm at antenna)
A0	48.5 to 57	-72 or lower
A1	51 to 57	-79 or lower
A2	51 to 57	-79 or lower
A3	53 to 57	MTL(90%) = -84 or lower
		MTL(15%) = -87 or lower

As a result of these differences, the maximum air-to-air range differs from class to class. Following are the values of air-to-air range as limited by these power level requirements. In other words, these are the air-to-air ranges in an interference-free environment. These results apply to a receiving aircraft having the worst-case value of MTL for that class, and they apply to 95 percent of transmitting aircraft whose transmitter power levels are characterized by the models described in Appendix P. Aircraft antenna gains for both transmitting aircraft and receiving aircraft are characterized by the TLAT antenna-gain model (ref., "*Technical Link Assessment Report*", Appendix D, RTCA Free Flight Select Committee, Eurocontrol ADS Programme, March 2001). For Class A0 and Class A1S, the results apply to a single bottom mounted antenna. For the other classes, the results apply to top-bottom antenna diversity.

Table E-2: Air-to-Air Range as Limited by Power

Avionics Classes	**Air-to-Air Range** (NM)
A0 to A0	10
A1S to A1	47
A1S to A2	47
A1S to A3	75
A1 to A1	66
A2 to A2	66
A3 to A3	140

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Appendix F

MASPS Compliance Matrix

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F. MASPS Compliance Matrix

F.1 Introduction

In previous versions of this document, Appendix F, in Section F.2, contained a traceability matrix mapping the compliance of these MOPS with all requirements specified in the ADS-B MASPS (RTCA DO-242/DO-242A). A similar traceability matrix was also produced for RTCA DO-282A, "*Minimum Operational Performance Standards (MOPS) for the Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast (ADS-B)*." These traceability matrices permitted both ADS-B link MOPS to be assessed as to their compliance with the ADS-B system requirements specified in the ADS-B MASPS.

F.2 ADS-B MASPS Compliance Matrix

The development of revised MOPS, for both UAT and 1090ES, has been performed in direct support of FAA and EASA rulemaking for ADS-B equipage, without first revising the ADS-B MASPS. Agreed-to changes which necessitate changes to ADS-B system requirements and are not merely link implementation specific have been documented in a series of Issue Papers maintained within RTCA Special Committee 186. These Issue Papers will serve as the basis for a future revision of the ADS-B MASPS (presumably RTCA DO-242B). At the time of publication of these MOPS, it is planned that part of any future revision of the ADS-B MASPS will include a matrix listing all MASPS requirements and mapping the corresponding requirement(s) from the current versions of both the UAT and 1090ES ADS-B link MOPS to the updated MASPS requirements.

F.3 Traffic Information Services – Broadcast (TIS-B) MASPS Compliance

TIS-B complements the operation of ADS-B by providing ground-to-air broadcast of surveillance data on aircraft that are not equipped for 1090 MHz ADS-B. The basis for this ground surveillance data may be an ATC Mode S radar, a surface or approach multilateration system or a multi-sensor data processing system. The TIS-B ground-to-air transmissions use the same signal formats as 1090 MHz ADS-B and can therefore be accepted by a 1090 MHz ADS-B receiver.

While the TIS-B MASPS were not completed at the time of the publication of these MOPS, it is anticipated that these MOPS will meet all of the requirements that flow down from the TIS-B MASPS.

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Appendix G

1090 MHz ADS-B Transition Issues for Avionics

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G 1090 MHz ADS-B Transition Issues for Avionics

G.1 Introduction

The objective of the 1090 MHz ADS-B System is to provide a real-time operational data interface between aircraft and ground vehicle user systems, and with ground-based Air Traffic System (ATS) controllers and automation. As a new technology component of operational systems, ADS-B will be introduced on an incremental basis to gain operational experience with the technology and to validate both the ADS-B delivery system and the implementation of applications that use ADS-B reports.

While this document addresses only the ADS-B equipment and its interfaces, ADS-B design and performance requirements must anticipate that applications, substantively supported by ADS-B reports, will be expected to provide users reliable, safe situational awareness and an acceptable basis for IFR operational procedures. Upon validation of ADS-B report and report delivery performance, ADS-B is intended to become a key component of systems used for the separation of aircraft.

This Appendix addresses transition issues for ADS-B avionics. ADS-B transition strategy and the evolution of ADS-B implementation within ATS ground systems and automation are discussed in Appendix D.

G.2 Air-to-Air ADS-B Applications

Initial demonstration of acceptable ADS-B performance and validation of acceptable designs of operator interfaces are likely to be based primarily upon air-to-air applications. Such applications identified for demonstration and potential early operational implementation include improved visual acquisition under VFR conditions, improved terminal operations in low visibility conditions, enhanced operations for en route and oceanic phases of flight, improved separation assurance in non-radar airspace, and parallel approaches to closely spaced runways under IFR conditions. ADS-B equipment implementations in air transport class platforms during this initial period are anticipated to take advantage of existing Mode S and TCAS avionics and will be integrated into airframes using existing on-board data busses and infrastructure. Other initial ADS-B implementations are likely to be optimized toward targeted initial applications — expandability of these implementations will be a key factor as the transition to ADS-B progresses. Implementation of the reception of Flight Information Service-Broadcast (FIS-B) and Traffic Information Service-Broadcast (TIS-B) information within ADS-B avionics may be considered.

G.3 Aircraft Integration

This document addresses both standalone implementations of ADS-B equipment and implementations integrated into existing aircraft configurations based on Mode S transponders and TCAS/ACAS equipment. Other aircraft integration issues include interfaces (e.g., to Flight Management Systems and GPS navigation equipment) to obtain source data for ADS-B messages. Separation of functions, specific interdependencies, hardware/software partitioning and failure detection/mitigation requirements must ensure the integrity, availability, and reliability of all functions to the extent necessary for the multiple services supported. Furthermore, as the NAS transitions to the use of GNSS, with appropriate augmentations for particular phases of operation, the ADS-B equipment should be able to use upgraded source data without the ADS-B equipment itself requiring retrofit.

1090 MHz technology is supported by U.S. and international standards specifically for ATS surveillance and separation services. Additionally, the technology is central to the collision avoidance function TCAS/ACAS now required for many commercial operators to provide an independent supplement to the ground-based ATS system. Implementation of 1090 MHz ADS-B data delivery capabilities will be facilitated through application and adaptation of existing standards and equipment to the maximum extent consistent with the ADS-B MASPS, RTCA DO-242A, in providing for air-to-air and air-to-ground situational awareness and separation support capabilities.

G.4 Air-Ground Surveillance Applications

For ground-based surveillance applications, initial validation of ADS-B will be supported, where possible, using the existing ground surveillance infrastructure. For example, it is intended that 1090 MHz ADS-B messages may be correlated against Secondary Surveillance Radars (SSRs) and enhancements made to those radars to support distribution of ADS-B information to appropriate ground-based systems. Further, transponder-based ADS-B implementations in aircraft are likely to be polled by SSRs when the ground-based surveillance systems require further data: such ADS-B implementations will need to support this interrogation.

G.5 Operational Approvals

It is recognized that data provided via ADS-B will be used in applications that will be evaluated on an end-to-end basis for each intended use. Approval of specific operational use will be predicated on the results of an analysis of the total systems involved. Data availability, reliability, and integrity will be a significant factor in these approvals. As operational experience with ADS-B is achieved, it is anticipated that application-specific standards will be developed to facilitate operational approvals.

Appendix H

Report Assembly Guidance

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H Report Assembly Guidance

H.1 Scope and Purpose

This Appendix is provided as a guide to the implementation of the Report Assembly Function in an ADS-B Receiving Subsystem. The actual *requirements* on the Report Assembly Function are to be found in Section 2 of this MOPS, particularly subsections §2.2.8 and §2.2.10. This Appendix is provided as a narrative guide to those requirements and to how they might be met.

H.2 Data Flow Into and Out Of the Report Assembly Function

See Figure H-1, which is a copy of Figure 2-15 from Section 2 of this document. The Report Assembly Function takes ADS-B Messages after they have been received and corrected for possible bit errors by the Message Input Processing. From these messages it composes ADS-B reports and delivers those reports to the report output storage buffer, from which they can be retrieved by the user application. The actual interface between the report output storage buffer and the ADS-B user application is beyond the scope of these MOPS.

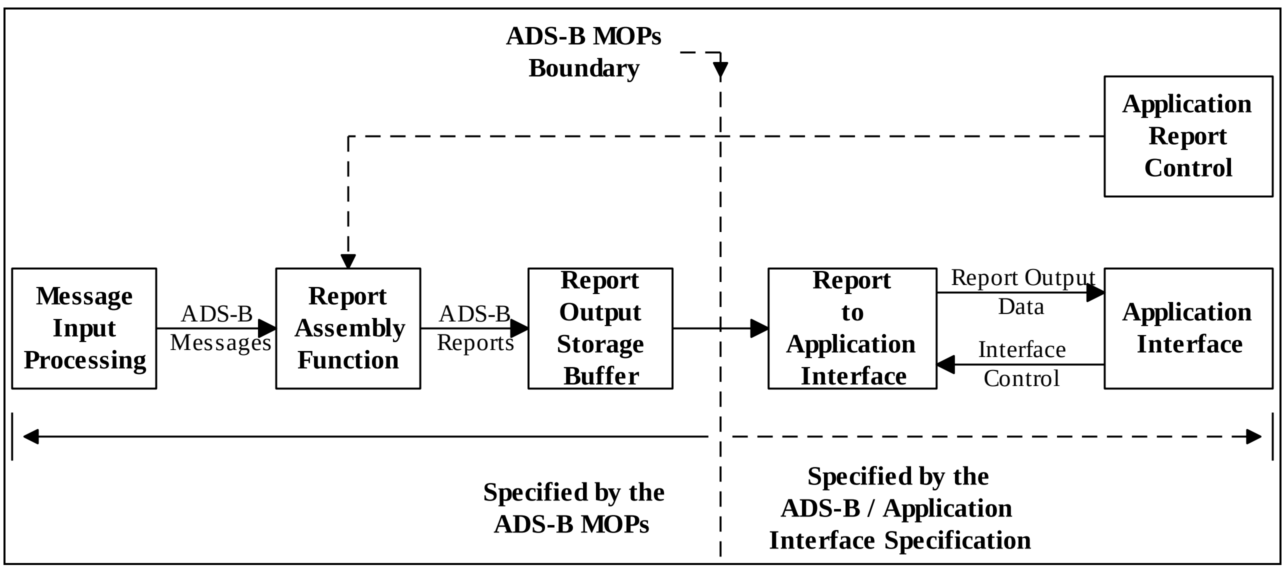

Figure H-1: ADS-B Message and Report General Data Flow.

H.2.1 Optional Report Control Interface

The dashed-line arrow in Figure H-1 represents an optional Report Control Interface by which an application may configure the output of the Report Assembly Function for its particular needs. The requirements on this optional interface have not been specified in this document. This interface, if present, might be used in the following ways.

a. The Report Control Interface could let the application specify for which ADS-B Participants it desires to receive reports, and for which participants it does not require reports. For instance, an application might specify, via the Report Control Interface, that it does not require reports for aircraft that are more than 50 nautical miles away from the own-ship. Again, the application might use the Report Control Interface to specify that it does not require reports concerning targets that are above (or below) a specified altitude.

b. The Report Control Interface could let the application specify, for specific targets, which report data elements are required and which may be omitted. For example, a Paired Approach application (as in RTCA DO-242A, §D.1.14) would require more information about the target with which the own-ship is paired for the approach than the a concurrently running Aid To Visual Acquisition application would require for other nearby ADS-B Participants.

H.2.2 Type 1 and Type 2 Report Assembly Functions

The concept of Type 1 and Type 2 Report Assembly Functions, as described in §2.2.6, subparagraphs "b" and "c," is similar to, but not quite the same as, that of the optional report control interface.

- A Type 2 Report Assembly Function has the full functionality. That is, it is capable of meeting all Report Assembly Function requirements. If a Report Control Interface is provided, then the user application may use that interface to throttle back the Report Assembly Function, causing it to provide fewer report elements for some or all of the targets.

- A Type 1 Report Assembly Function has reduced functionality customized for a particular set of user applications. Although the outputs of a Type 1 Report Assembly Function are similar to those of a Type 2 function with a Report Control Interface, in the case of the Type 1 function it has already been statically pre-configured to meet the specific needs of a particular user application or set of applications.

H.2.3 TIS-B Report Assembly Function

The requirements for the generation of TIS-B reports are provided in §2.2.17.4.6. These MOPS do not specify the reporting format for TIS-B reports. However, the information content is specified by §2.2.17.4.6. The generation of TIS-B reports is substantially less complex than ADS-B report generation since in the former case the report elements, except for position and Time of Applicability, are directly mapped from the TIS-B message contents. The remainder of this Appendix deals only with the ADS-B report generation function.

H.3 Messages and Reports

H.3.1 ADS-B Messages (Input Data for Report Assembly)

Table H-1 lists the types of ADS-B Messages that may be received and used when assembling ADS-B reports.

Table H-1: 1090 MHz ADS-B Message Types

Message Type	Reference Section
ADS-B Airborne Position	§2.2.3.2.3
ADS-B Surface Position	§2.2.3.2.4
ADS-B Aircraft Identification and Category	§2.2.3.2.5
ADS-B Airborne Velocity Message	§2.2.3.2.6
Target State and Status	§2.2.3.2.7.1
Aircraft Operational Status	§2.2.3.2.7.2
Extended Squitter Aircraft Status	§2.2.3.2.7.8

H.3.2 ADS-B Reports (Data Delivered By Report Assembly Function)

H.3.2.1 State Vector Reports

Table H-2 lists the fields in State Vector (SV) Reports and the sources of the data in those fields.

The SV Report contains three different Times of Applicability (TOA): TOA-P, TOA-V, and TOA-R. The third column of Table H-2 indicates for each SV Report element, which of these three times of applicability is the TOA for that report element. In a minimum system, in which the Report Assembly Function outputs SV Reports only when a position or velocity message is received, TOA-R, the Time of Applicability of the SV Report, would always be either TOA-P or TOA-V, the Time of Applicability of the position or velocity message which triggered the outputting of that report. In a more-than-minimum system that outputs SV Reports at additional times, the TOA of the report, TOA-R, may differ from either TOA-P or TOA-V. For Aircraft/Vehicles on the airport surface, both position and velocity related information are conveyed within the Surface Position Messages (§2.2.3.2.4). Therefore the TOA for the SV Report elements associated with both position and velocity information are listed in Table H-2 as TOA-P.

Table H-2: State Vector Report Data

Item #	State Vector Report Subfield	TOA	Obtained From
0a	Report Type	TOA R	Report Assembly Function
0b	Report Structure	TOA R	Report Assembly Function
0c	Validity Flags	TOA R	Report Assembly Function
1	Participant Address	TOA R	All message types AA subfield
2	Address Qualifier	TOA R	Aircraft Identification and Category Message and for all message types received from non-transponder devices (i.e.., DF=18) the CF subfield
3	Report Time of Applicability (Position and Velocity) (see note 4)		Provided by Report Assembly Function
4	Encoded Latitude (WGS-84)	TOA P	Airborne Position Message or Surface Position Message
5	Encoded Longitude (WGS-84)	TOA P	Airborne Position Message or Surface Position Message
6	Altitude, Geometric (see note 1) (WGS-84)	TOA R	Computed by Report Assembly Function
7	North / South Velocity	TOA V	Airborne Velocity Message
8	East / West Velocity	TOA V	Airborne Velocity Message
9	Ground Speed while on the Surface	TOA P	Surface Position Message
10	Heading while on the Surface	TOA P	Surface Position Message
11	Altitude, Barometric (Pressure Altitude)	TOA P	Airborne Position Message
12	Vertical Rate, Geometric/Barometric (WGS-84)	TOA V	Airborne Velocity Message
13	Navigation Integrity Category (NIC)	TOA P	Airborne Position Message or Surface Position Message
14	Estimated Latitude (WGS-84)	TOA R	Estimate Computed by Report Assembly Function
15	Estimated Longitude (WGS-84)	TOA R	Estimate Computed by Report Assembly Function
16	Estimated North/South Velocity	TOA R	Estimate Computed by Report Assembly Function
17	Estimated East/West Velocity	TOA R	Estimate Computed by Report Assembly Function
18	Surveillance Status/Discretes (see note 3)	TOA R	Airborne Position and Airborne Velocity Messages
19	Report Mode	TOA R	Report Assembly Function

Notes:

1. *The Geometric Altitude must be computed by the Report Assembly Function, using the barometric pressure altitude from the Airborne Position Message and the difference between barometric and geometric altitudes from the Airborne Velocity Message. §H.4.3 below describes one acceptable computation method.*

2. *The Airspeed and Magnetic Heading values are only available from Airborne Participants that are not providing information about their velocities over the ground. Normally, an Airborne Participant would emit "Subtype 1" or "Subtype 2" Airborne Position Messages, which do provide the N/S and E/W components of its velocity over the ground. But, if velocity over the ground were not available, an Airborne Participant could emit "Subtype 3" or "Subtype 4" Velocity Messages, that contain Airspeed and Heading fields.*

3. *The Surveillance Status/Discretes includes elements mapped from both the Airborne Position and the Airborne Velocity Messages. See §2.2.8.1.21 for details.*

4. *The "Report Time of Applicability" field, as defined in §2.2.8.1.4, contains three separate data sub-elements for reporting the Time of Applicability (TOA) for: TOA-R for the estimated position and estimate velocity information; TOA-P the position information; and TOA-V for the velocity information.*

5. *For details of the fields in SV Reports, see §2.2.8.1 of this document and subsections of that section.*

H.3.2.2 Mode Status Reports

Table H-3 lists the fields in Mode Status (MS) Reports and the sources of the data in those fields.

Table H-3: Mode Status Report Data

Item #	Mode Status Report Subfield	Obtained From
0a	Report Type	Report Assembly Function
0b	Report Structure	Report Assembly Function
0c	Validity Flags	Report Assembly Function
1	Participant Address	All Message Types AA Field
2	Address Qualifier	Aircraft Identification and Category Message and for Aircraft Operational Status Messages received from Non-Transponder Devices (i.e.., DF=18) the CF subfield
3	Time of Applicability	Report Assembly Function
4	ADS-B Version	Aircraft Operational Status Message
5a	Call Sign	Aircraft Identification and Category Message
5b	Emitter Category	Aircraft Identification and Category Message
5c	A/V Length and Width Codes	Aircraft Operational Status Message
6	Emergency/Priority Status	Extended Squitter Status Message – Subtype 1
7	Capability Codes	Aircraft Operational Status Message –and- Target State and Status Message
8	Operational Mode	Aircraft Operational Status Message –and- Target State and Status Message
9a	SV Quality - NAC_P	Aircraft Operational Status Message –or- Target State and Status Message
9b	SV Quality - NAC_V	Airborne Velocity Message
9c	SV Quality – SIL	Aircraft Operational Status Message –or- Target State and Status Message
9d	SV Quality – GVA	Aircraft Operational Status Message
9e	SV Quality – NIC_{BARO}	Aircraft Operational Status Message –or- Target State and Status Message
10a	Track/Heading and HRD	Aircraft Operational Status Message
10b	Vertical Rate Type	Airborne Velocity Message
11	Other (Reserved)	N/A

Notes:

1. *Certain message parameters are conveyed within both the Aircraft Operational Status Message and also within the Target State and Status Message. In this case the Mode Status Report will use the most recently received message that contains the required data element (i.e., source will be either the Aircraft Operational Status Message* <u>*OR*</u> *the Target State and Status Message. In the case of the Capability Codes and Operational Mode parameters, the Target State and Status Message conveys only a subset of the codes conveyed by the Aircraft Operational Status Message. For this case the Mode Status Report will report the codes always using data from the Aircraft Operational Status Message for those codes only reported in this message type. For the case where the same codes are conveyed in both message types, then the most recently received message will be used for Report Assembly. Thus when both message types are being received a combination of data extracted from the Aircraft Operational Status Message* <u>*AND*</u> *the Target State and Status Message may be required to fully report the most current Capability Codes and Operational Status.*

2. *For details of the fields in Mode Status Reports, see §2.2.8.2 of this document and subsections of that section.*

H.3.2.3 Target State Reports

Table H-4 lists the fields in Target State Reports and the sources of the data in those fields.

Table H-4: Target State Report Data

Item #	TS Report Subfield	Obtained From
0a	Report Type	Report Assembly Function
0b	Report Structure	Report Assembly Function
1	Participant Address	Report Assembly Function
2	Address Qualifier	All Message Types AA Field
3	Report Time of Applicability	Aircraft Identification and Category Message and for Target State and Status Messages received from Non-Transponder Devices (i.e., DF=18) the CF subfield
4a	Horizontal Intent: Horizontal Data Available & Horizontal Target Source Indicator	Target State and Status Message
4b	Horizontal Intent: Target Heading or Track Angle	Target State and Status Message
4c	Horizontal Intent: Target Heading/Track Indicator	Target State and Status Message
4d	Horizontal Intent: Reserved for Heading/Track Capability	N/A
4e	Horizontal Intent: Horizontal Mode Indicator	Target State and Status Message
4f	Horizontal Intent: Reserved for Horizontal Conformance	N/A
5a	Vertical Intent: Vertical Data Available & Vertical Target Source Indicator	Target State and Status Message
5b	Vertical Intent: Target Altitude	Target State and Status Message
5c	Vertical Intent: Target Altitude Type	Target State and Status Message
5d	Vertical Intent: Target Altitude Capability	Target State and Status Message
5e	Vertical Intent: Vertical Mode Indicator	Target State and Status Message
5f	Vertical Intent: Reserved for Vertical Conformance	N/A

Note: *For details of the fields in Target State Reports, see §2.2.8.3.1 of this document and subsections of that section.*

H.3.2.4 Air Reference Velocity Reports

Table H-5 lists the fields in Air Referenced Velocity (ARV) Reports and the sources of the data in those fields.

Table H-5: Air Referenced Velocity Report Data

Item #	TS Report Subfield	Obtained From
0a	Report Type	Report Assembly Function
0b	Report Structure	Report Assembly Function
0c	Validity Flags	
1	Participant Address	Report Assembly Function
2	Address Qualifier	Airborne Velocity Message Subtype 3 or 4 AA Field
3	Report Time of Applicability	Airborne Velocity Message Subtype 3 or 4
4a	Airspeed	Airborne Velocity Message Subtype 3 or 4
4b	Airspeed Type	Airborne Velocity Message Subtype 3
5	Heading While Airborne	Airborne Velocity Message Subtype 3

Note: *For details of the fields in Air Referenced Velocity Reports, see §2.2.8.3.2 of this document and subsections of that section.*

H.4 Estimating Report Field Values

Notice from Table H-2 in §H.3.2.1 above that not all of the information required in the fields of a State Vector (SV) Report is received in the same type of message. Indeed, some SV Report elements, such the Geometric Altitude, can only be computed by combining information from more than one type of 1090 MHz ADS-B Message.

Notice also that “Estimated Latitude,” “Estimated Longitude,” “Estimated N/S Velocity,” and “Estimated E/W Velocity” fields, SV Report items #14 to #17, all have TOA-R as their Times of Applicability. These fields together present an estimate of the horizontal position and horizontal velocity that is time-registered to the same Time of Applicability.

The Report Assembly Function must estimate the values of the horizontal position (latitude and longitude) SV Report elements at TOA-R, the Time of Applicability of the report, based on the data received in Position and Velocity Messages that are received at different times. At the option of the implementer, the SV Report may also contain estimated horizontal velocity fields that are applicable at TOA-R. This estimation may be implemented in a variety of ways, such as by alpha-beta filters, alpha-beta-gamma filters, Kalman filters, or linear extrapolation. The following subparagraphs discuss the estimation of some of the SV Report field elements in a little more detail.

H.4.1 Estimating Horizontal Position (Latitude and Longitude)

SV Report elements #14 and #15, "Estimated Latitude" and "Estimated Longitude," contain the position of the ADS-B Participant at the Time of Applicability of the SV Report (TOA-R, a sub-element of SV item #3). For an Airborne Participant, the Report Assembly Function must estimate the horizontal position of that participant at the Time of Applicability of the Report (TOA-R) based on the values it has received in Airborne Position and Airborne Velocity Messages from that ADS-B Participant.

As Figure H-2 illustrates, at most latitudes – everywhere except in very close proximity to the N or S pole – the change in latitude, $\Delta\phi$, and the change in longitude, $\Delta\lambda$, due to the own-ship moving for a short time Δt with East-West velocity component *dx/dt* and North-South velocity component *dy/dt* may be approximated by the formulas

$$\Delta x = \frac{dx}{dt}\Delta t = R \cdot \Delta\lambda \cdot \cos\phi$$

$$\Delta y = \frac{dy}{dt}\Delta t = R \cdot \Delta\phi$$

where R is the radius of the sphere used to represent the earth and latitude, ϕ, and longitude, λ, are expressed in radians.

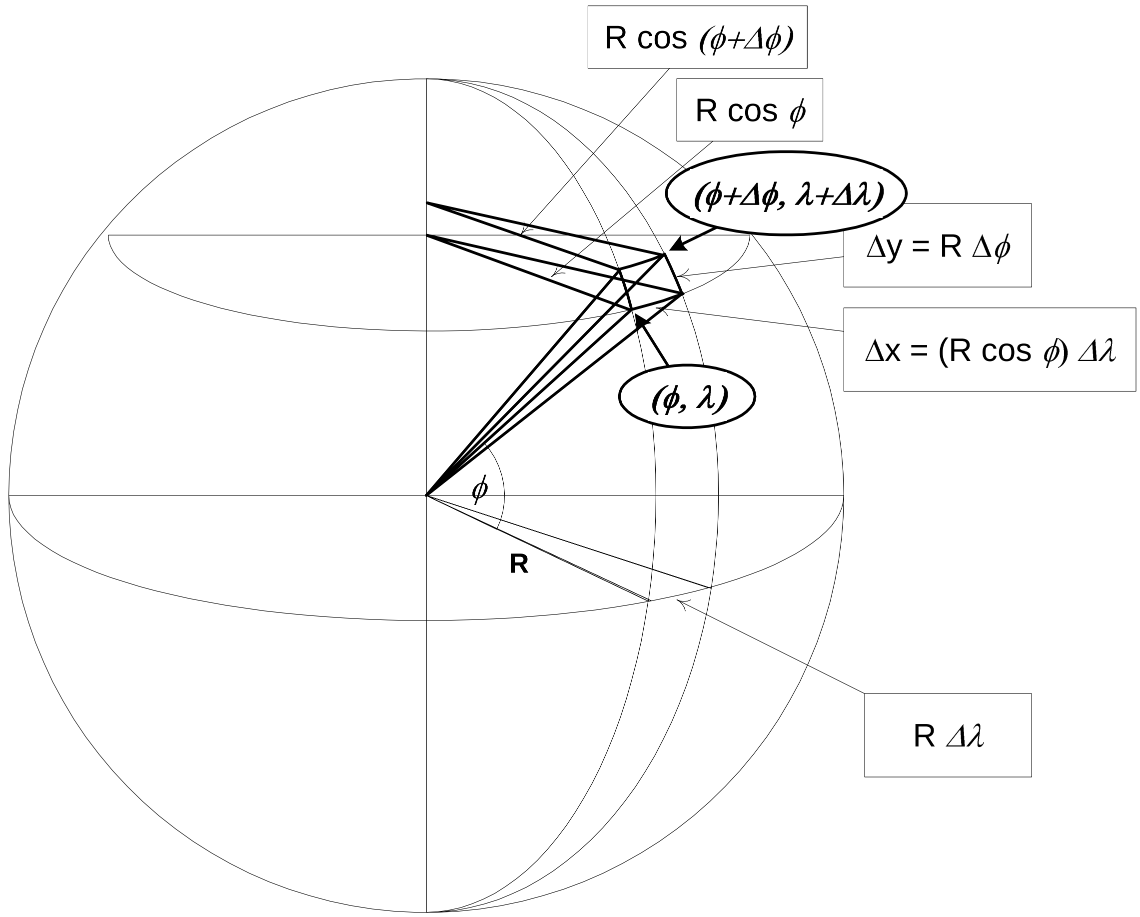

Figure H-2: Expressing a Small Change in Latitude and Longitude (ϕ, λ) As a Change in Local Cartesian Coordinates (x,y).

If the radius R of the sphere used to represent the earth is chosen so that one minute of arc on a meridian – one minute of latitude – is one nautical mile, and the velocities V_{NS} and V_{EW} are expressed in knots (nautical miles per hour), and the changes in latitude and in longitude are expressed in degrees, then the formulas become

$$\Delta Latitude_{degrees} = \frac{V_{NS} \cdot \Delta t_{seconds}}{3600}$$

$$\Delta Longitude_{degrees} = \frac{V_{EW} \cdot \Delta t_{seconds}}{3600 \cdot \cos(Latitude)}$$

This approximation is adequate for extrapolating the position of an ADS-B Participant forward in time over an interval Δt of a few seconds.

For the case when the target position is very close to the North or South pole, however, where the cosine of the latitude approaches zero, the above approximation is inadequate. Figure H-3 shows the situation for an ADS-B Participant that is in close proximity to the pole. As Figure H-3 shows, for such a situation the latitude-longitude graticule is no longer adequately represented by a rectangular grid. If ADS-B Receiving Subsystem is to be used in aircraft that travels over the poles, the position-extrapolation algorithm used in that equipment should be designed to handle the situation shown in Figure H-3. Implementers should take particular care when the (North or South) own-ship latitude exceeds 89 degrees.

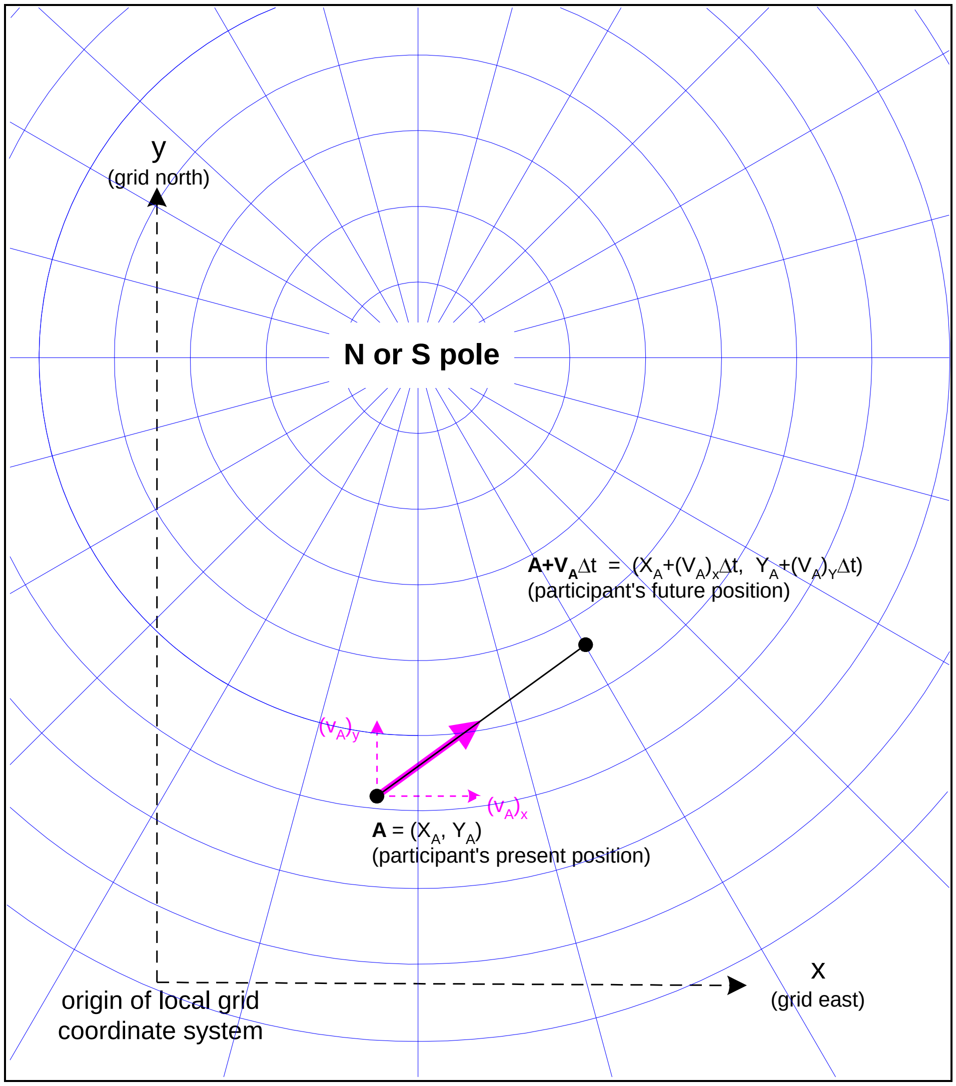

Figure H-3: Non-Rectangular Latitude/Longitude Graticule Near the Poles.

H.4.2 Estimating Horizontal Velocity

State Vector Report elements #7 and #8, "North/South Velocity" and "East/West Velocity," contain the horizontal velocity of an airborne ADS-B Participant as received in the most recent Airborne Velocity Message from that ADS-B Participant. The Time of Applicability of these Report elements is the Time of Applicability of that most recent Airborne Velocity Message (TOA-V, a sub-element of SV item #3), so no estimation or extrapolation is required.

Likewise, SV Report elements #9 and #10, "Ground Speed" and "Heading While on the Surface" contain the horizontal velocity of a surface ADS-B Participant as received in the "Movement" and "Heading" fields of the most recent Surface Position Message from that

ADS-B Participant. The Time of Applicability of these Report elements is the Time of Applicability of that Surface Position Message (TOA-P, a sub-element of SV item #3), so no estimation or extrapolation is required; the E/W and N/S south components of the "Estimated Velocity" are merely computed by converting the velocity from polar form (Ground Speed and Heading) to rectangular form (E/W and N/S velocity).

However, SV Report elements #16 and #17, "Estimated North/South Velocity" and "Estimated East/West Velocity" contain the participant's horizontal velocity at time TOA-R, the Time of Applicability of the SV Report, which may not be the same as the Time of Applicability of the most recent Velocity Message. These Report elements are optional at the discretion of the implementer (see §2.2.8.1.19 and §2.2.8.1.20). If these Report elements are provided, the estimation may be done in a variety of ways, including linear extrapolation, alpha-beta or alpha-beta-gamma filters, and Kalman filters. Appendix K discusses the results of simulation studies for some of these methods.

H.4.3 Computing Geometric Altitude (Height Above WGS-84 Ellipsoid)

If an Airborne Position Message from a particular ADS-B Participant has TYPE Code 20, 21, or 22, then the "altitude" field in that message contains the geometric altitude (Height Above WGS-84 Ellipsoid) for that ADS-B Participant at the Time of Applicability of that Message. But SV Report element #6, "geometric altitude" is the altitude at TOA-R, the Time of Applicability of the SV Report, not the Time of Applicability of the Airborne Position Message. The ADS-B Report Assembly Function must compute the geometric altitude, h, at the Time of Applicability of the Report, $t_R = TOA\text{-}R$. This could be done by linear extrapolation, by an alpha-beta filter, alpha-beta-gamma-filter, or Kalman filter.

Most Airborne Position Messages, however, will have TYPE Codes in the range from 9 to 18, indicating that their "altitude" fields contain barometric pressure altitude, H_P, rather than the geometric altitude, h. It is still possible for the Report Assembly Function to estimate a value for SV element #6, geometric altitude, at the Time of Applicability of the SV Report, $t_R = TOA\text{-}R$. One way to do this would be by linear extrapolation, using

- $H_P(t_P)$, the pressure altitude from the most recently received Airborne Position Message,
- $Diff(t_V)$, the difference of geometric altitude from pressure altitude, from the most recently received Airborne Velocity Message, and
- dH_P/dt or dh/dt, the vertical rate from the most recently received Airborne Velocity Message.

Let:

$H_P(t_P)$ = barometric pressure altitude from the most recent Airborne Position Message, for which the Time of Applicability is $t_P = TOA\text{-}P$,

$Diff(t) = h(t) - H_P(t)$ = difference between geometric altitude, h, and barometric pressure altitude, H_P, as a function of time, t, and

$h(t_R)$ = geometric altitude, h, at the time of validity, $t_R = TOA\text{-}R$, of the SV Report

Then $h(t_R)$, the geometric altitude at the Time of Applicability of the SV Report, could be estimated as follows:

$$h(t_R) = H_P(t_R) + Diff(t_R)$$

$$= H_P(t_P) + (t_R - t_P)\frac{dH_p}{dt} + Diff(t_V) + (t_R - t_V)\frac{d}{dt}(h - H_P)$$

If the rate of change of the difference, $Diff = h - H_P$, is small, it might be ignored, so that the final term in the above formula, "$(t_R\text{-}t_V)\cdot d(h\text{-}H_P)/dt$" is omitted. It would probably be appropriate, however, to track $Diff = (h\text{-}H_P)$ as received in successive Airborne Velocity Messages. The tracking filter, which might be an alpha-beta filter, an alpha-beta-gamma filter, or a Kalman filter, could then provide an estimate of the rate of change, $d(h\text{-}H_P)/dt$.

H.5 Tracking ADS-B Participants

The ADS-B Report Assembly Function must assemble reports giving the status of multiple ADS-B Participants. With respect to each such Participant, the Report Assembly Function transitions between several states, as specified in §2.2.10.

When the first message from a Participant is received, the Report Assembly Function enters "Initialization State" with respect to that participant. It assigns a block of memory to hold messages from that Participant.

When both "**even**" and "**odd**" Airborne Position or Surface Position Messages have been received from the Participant, so that an unambiguous decoding of the Participant's CPR-encoded position into latitude and longitude can be performed, the Report Assembly Function enters "Acquisition State" with respect to that Participant and begins to output SV Reports for that Participant into the Report Output Storage Buffer. The "Report Mode" field in those reports (SV item #19) is set to indicate "Acquisition Mode."

When both an unambiguously decoded position and a velocity have been received for the participant, the Report Assembly Function enters "Track State" for that participant, and begins to output SV Reports in which the "Report Mode" field is set to "Track."

H.6 Track Acquisition and Coast Considerations

State Vector update intervals of 3 (three) seconds are required (1 second desired) by the ADS-B MASPS for short range surveillance applications. Long range airspace deconfliction applications, on the other hand, can be supported by state vector update intervals of 12 seconds or longer dependent on range. Track files must be initiated and maintained on all ADS-B Participants of interest to the supported applications, while the different applications are likely to have different target acquisition and track maintenance needs.

Recognizing this, this document requires the ADS-B Report Assembly Function to retain information on an ADS-B System Participant for at least 200 seconds when the Report Assembly Function is in "Acquisition" or "Track" state with respect to that participant. The information provided in the State Vector Reports (i.e., separate times of applicability for velocity, position, and estimated (i.e. time-registered) position and velocity information), combined with the fact that ADS-B Reports are not required to be generated for an ADS-B Participant unless a new ADS-B Message has been received from that Participant, gives the following characteristics to a minimum system:

- Information may be associated with and retained for an ADS-B Participant longer than required for the particular applications serviced by the ADS-B Receiving Subsystem.
- The ADS-B application has the information required for it to make all necessary determinations on coasting, dropping, etc., of an ADS-B System Participant.
- Acquisition/reacquisition time for ADS-B System Participants is reduced.

ADS-B implementations which output ADS-B Reports for a System Participant without receiving a new ADS-B Message from that Participant contain a separate Time of Applicability for the extrapolated State Vector information. By comparing the various Times of Applicability in the SV Report, the application will be able to determine the risk of error in the extrapolated ADS-B Report.

Appendix I

Extended Squitter Enhanced Reception Techniques

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I Extended Squitter Enhanced Reception Techniques

I.1 Purpose and Scope

The purpose of this Appendix is to provide a description of improved squitter reception techniques. Elements of improved squitter reception include (1) the use of amplitude to improve bit and confidence declaration accuracy, (2) more capable error detection/correction algorithms, (3) more selective preamble detection approaches, and (4) combinations of the above.

The improved techniques presented in this Appendix represent one way of achieving the performance requirements specified in §2.2.4.4 for enhanced squitter reception. The squitter processing configuration used as the basis for these performance requirements is specified in §I.5.

The reception techniques, as required in §2.2.4.3.4 of these MOPS, are also described in this appendix for comparison with the enhancements.

I.2 Background

Squitter reception includes the detection of the Mode S 1090 MHz waveform preamble, declaration of the bit and confidence values, error detection, and (if necessary) error correction. The current techniques for squitter reception are based upon techniques developed for use in Mode S narrow-beam interrogators and for TCAS. In both of these applications, the rate of Mode A/C FRUIT (see glossary) that is stronger than the Mode S waveform is relatively low, nominally less than 4,000 FRUIT per second.

Early applications investigated for Extended Squitter, prior to the development of this document, included long range air-ground surveillance, surface surveillance and support for TCAS. Of these three applications, the only one with the potential for operating in significantly higher FRUIT environments was the air-ground application. For this application, it is possible to use sectorized antennas (6 to 12 sectors) to limit the amount of FRUIT detected by any receiver.

Extended Squitter applications have now been defined in DO-242A, including long range (up to 90 NM) air-air surveillance in support of free flight. This type of surveillance is referred to as Cockpit Display of Traffic Information (CDTI). For this application, sectorized antennas are not an option. In high-density environments, it is possible to operate with FRUIT rates of 40,000 FRUIT per second and higher.

Even with these FRUIT rates, Extended Squitter reception using current techniques will provide useful performance. However, operation of Extended Squitter in very high Mode A/C FRUIT environments has led to the development of improved squitter reception techniques to support long range CDTI in high-density environments.

I.3 Current Squitter Reception Techniques

Receiving systems for Mode S replies and squitters are currently implemented operationally in ground based Mode S interrogator/receiver systems and in TCAS avionics. For TCAS, the current reception techniques are defined in DO-185B. These current reception techniques are the basis for the reception requirements in these MOPS (section 2.2). The enhanced techniques that are the subject of this Appendix are not required in this version of the MOPS, but are planned to be required in a future version.

I.3.1 Overview of Current Techniques

Extended squitter uses the 112-bit Mode S waveform shown in Figure I-1. Other than bit assignments, this is the same as the long reply waveform currently used operationally for air-ground replies and for air-air coordination messages in TCAS. This waveform encodes data using pulse position modulation (PPM). A chip in the leading half of the bit position represents a binary ONE. A chip in the trailing half bit position represents a binary ZERO. Reception of the Squitter begins with the detection of the four-pulse preamble. At preamble detection a dynamic threshold is set 6 dB below the level of the preamble. Any signal received below this threshold will not be seen by the squitter reception processor. This eliminates the effect of low level Mode A/C and Mode S FRUIT on the reception process.

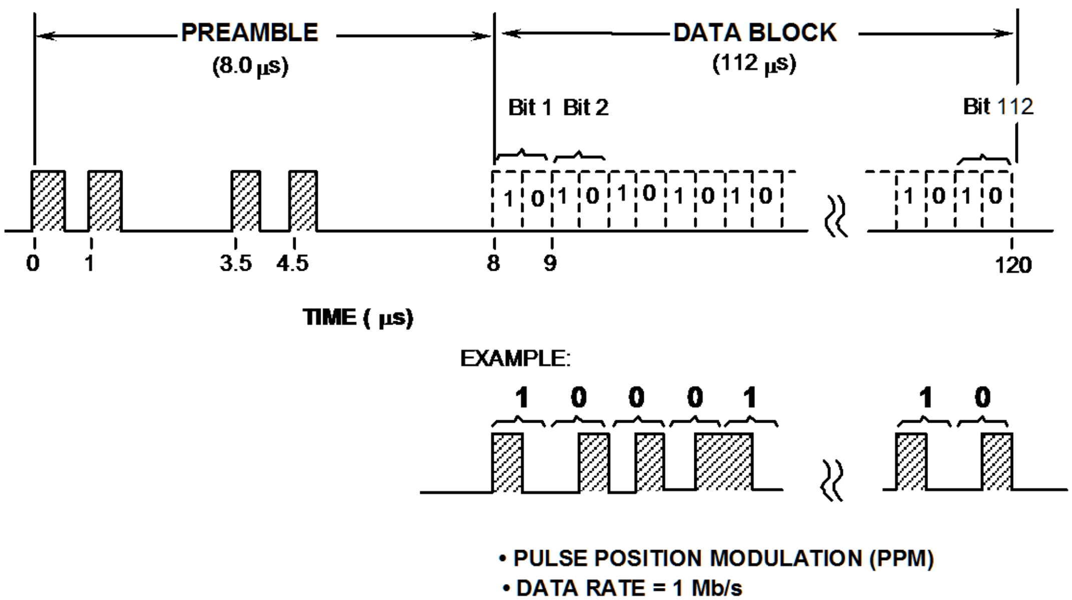


Figure I-1: **Mode S Extended Squitter Waveform**

Once all of the bits have been received, error detection is performed using the 24-bit CRC contained in the PI field. If no error is detected, the squitter is passed on to surveillance processing. If an error is detected (indicated by a non-zero error syndrome) an error correction technique is applied. The current error correction algorithm can correct the errors caused by one stronger overlapping Mode A/C FRUIT.

I.3.2 Current Techniques for Bit and Confidence Declaration

Currently, bit values are declared by comparing the amplitudes of the centers of the two chips; the chip with the greater amplitude is declared the bit value. This amplitude comparison technique limits bit errors caused by FRUIT of lower level than the squitter being received (Figure I-2, parts a and b).

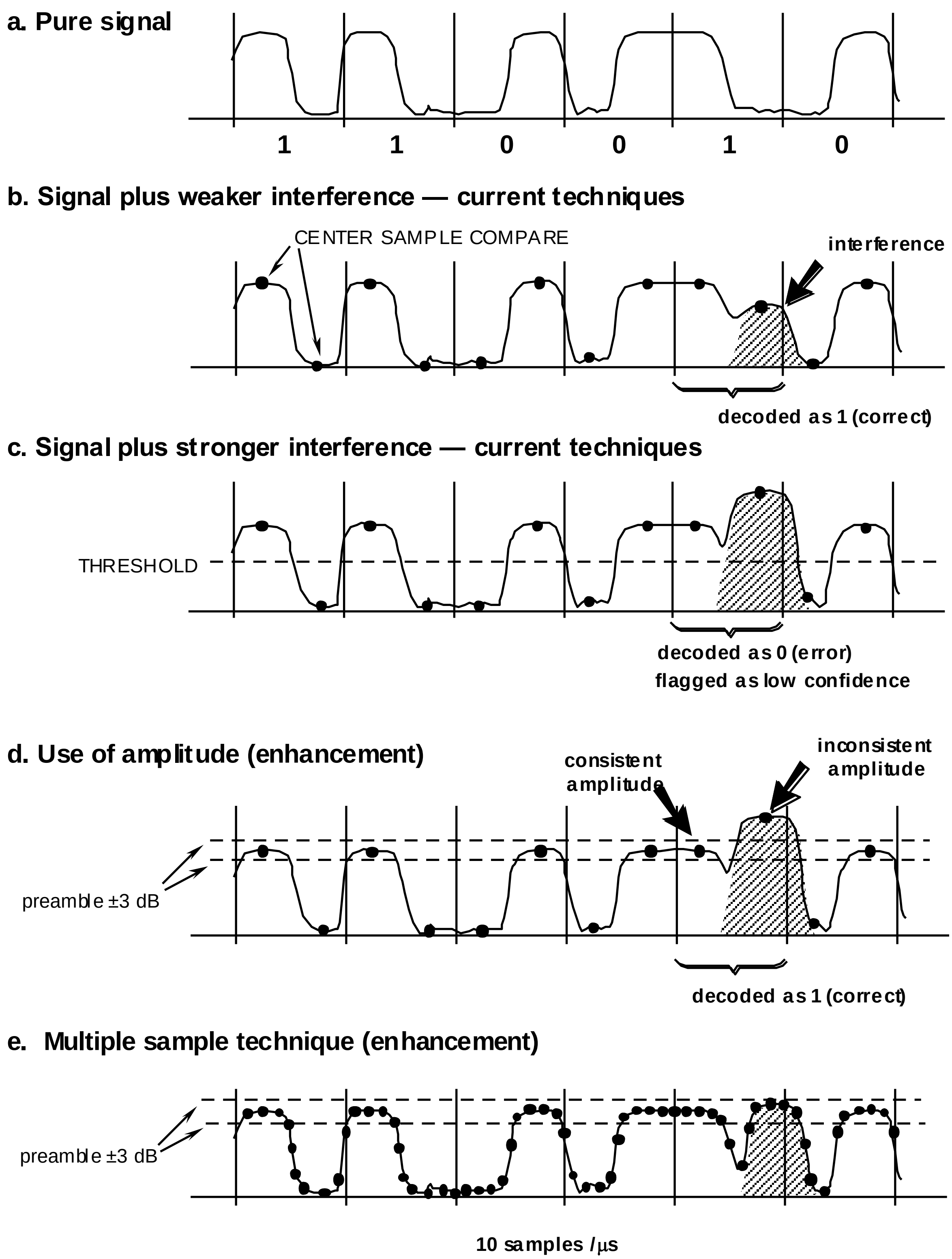


Figure I-2: Current and Enhanced Bit Demodulation Techniques

Note: *The vertical scale represents log video signals.*

Currently confidence for each bit is declared by observing if signals are above threshold on both chips. If only one chip is above threshold, it is declared to be high confidence since there is no evidence of overlapping FRUIT. If both chips have amplitude above threshold, low confidence is declared since some form of interference had to be present to cause this condition (Figure I-2, part c).

Since the nominal width of a Mode A/C pulse is 0.45 microsecond, an interfering Mode A/C pulse can affect only 1 of the 2 chips of a Mode S bit position. If the chip affected is the one with the Mode S pulse, the level of the pulse in the chip will be altered, but since it is the only chip with energy, the bit will be declared as high confidence. If instead the interfering pulse affects the blank chip, pulses will exist in both positions and the Mode S bit will be declared as low confidence. Since the bit decision is based on the larger pulse, if the Mode A/C FRUIT is stronger than the Mode S signal, any such bit will be declared in error, while if the Mode S signal is stronger, any such bit will be declared correctly.

I.3.3 Current Error Detection and Correction Techniques

I.3.3.1 Overview

When a Mode A/C FRUIT interferes with a Mode S Extended Squitter, some of the Mode S bits may be declared in error. The current Mode S error correction algorithm attempts to correct these errors by locating a string of 24 consecutive bits such that the low confidence bits in the window cover the bits in the corresponding error syndrome [reference I-1]. If such a window is found, all low confidence bits matching the syndrome are flipped, and the message is declared correct.

I.3.3.2 Sliding Window Technique

This algorithm operates by examining successive 24 bit windows, starting with bits 89-112 of the message. In order to achieve a successful error correction, each message bit in the window corresponding to a one (1) in the error syndrome must have its value complemented (i.e., a one is changed to a zero (0) and a zero is changed to a one). This complementing can only be done if each of the bits is declared to be low confidence. If so, each of the bits is complemented and the message is declared to be error corrected. If not, the window is shifted one bit downward, a transformed syndrome is computed and the process repeats. The process ends when a correctable error pattern has been found, or the sliding window reaches the beginning of the message. In order to control undetected errors, correction is not attempted if there are more than 12 low confidence bits in the window.

This technique provides error correction in cases where a Mode S message has been overlaid with one stronger Mode A/C FRUIT (that caused all bit errors) and one or more weaker Mode A/C FRUIT that were above the dynamic threshold (and caused only low confidence bits). This technique is well suited to the low levels of Mode A/C FRUIT observed in a narrow-beam Mode S interrogator or a TCAS. This technique is not appropriate for high FRUIT rate environments since it produces a high undetected error rate; for this reason, its use is prohibited in §2.2.4.4.

I.4 Enhanced Squitter Reception Techniques

I.4.1 Enhanced Preamble Detection

Preamble detection identifies the beginning of an Extended Squitter reception. The process has two outputs: (1) the start time of the signal and (2) the received power level of this signal. This process includes validation that uses the receptions during the first 5 bits in the data block and several other validation tests. Following is a description of a particular enhanced preamble detection technique that has been used successfully in achieving the performance required in these MOPS.

I.4.1.1 Log Video Samples

The preamble detection process described here operates on data in the form of samples of the log video received waveform. Specifically, the sample rate is 10 samples per microsecond, although other sample rates, including 8 samples per microsecond, have been found to be effective. In developing these enhanced decoding techniques, both an 8 MHz and 10 MHz sampling rate implementation were tested. It was determined that the 10 MHz sampling rate yielded better reception performance. In general, a higher sampling rate will perform better because of more samples for bit and confidence decoding. For these MOPS, the 10 MHz sampling rate implementation was used to establish the reception performance required for Class A3 equipment, and the 8 MHz sampling rate implementation was used to set the required performance for the Class A2 equipment.

I.4.1.2 Threshold

The preamble detection process includes a threshold power level used to discard very weak receptions. Typical value = -88 dBm (referred to the antenna) for an A3 receiver. The Minimum Triggering Level (MTL), which is the point of 90 percent receptions in the absence of interference, is typically about 4 dB higher than the threshold.

I.4.1.3 Valid Pulse Position

A sample that is above threshold and also is followed consecutively by **N** or more samples above threshold is defined to be a "Valid Pulse Position." If the sample rate is 10 per microsecond, then **N** = 3. This definition has the effect of defining a pulse as an event in which at least 4 consecutive samples are above threshold. For other sample rates, **N** is adjusted so that a pulse is declared when the signal is above threshold for more than 0.3 microseconds.

I.4.1.4 Leading Edge

A Leading Edge is declared for a particular sample if it is a Valid Pulse Position and also has substantial slope in the interval before this sample and less than substantial slope in the next interval. Substantial slope is defined by the power change between one sample and the next. The slope threshold is 48 dB per microsecond (applicable to receiver bandwidth of approximately 8 MHz). Therefore if the sample rate is 10 samples per microsecond, the threshold is 4.8 dB.

I.4.1.5 Initial Detection of a 4-Pulse Preamble

The preamble detection process begins when four pulses have been detected, having the spacing of the Mode S preamble. The detection criterion is:

• Finding four pulses having timing of 0 - 1.0 - 3.5 - 4.5 microsecond
• Two or more of these must be Leading Edges.
• The others can be Valid Pulse Positions
• Sample tolerance can be plus or minus 1 (but not both)

Note that the power levels in the four pulses need not agree. Note also that trailing edges are not used.

I.4.1.6 Arrival Time

The signal arrival time is initially estimated to be the leading edge of the first of these four pulses. Subsequently this is adjusted by +1 or -1 sample if two or more of the other three pulses have leading edges with that timing.

I.4.1.7 Reference Level Generation

A Reference Power Level is generated during preamble detection for use in re-triggering and during demodulation of the data block. Step 1 is to identify a set of samples to use. Among the four preamble pulses, those whose leading edges agree with the preamble timing are used; samples from the other pulses are not used. Next, for each pulse used, select the **M** samples after the leading edge sample. If the sample rate is 10 per microsecond, then **M** = 3. For other sample rates, the value of **M** is equal to the value of **N** defined in §I.4.1.3.

Step 2 is an algorithm to generate the Reference Level from these samples. For each sample, compute the number of other samples that are within 2 dB. Then find the maximum of these counts. If the maximum count is unique, then the sample used to form that count is taken to be the Reference Level.

Otherwise, when there are two or more samples whose counts are maximum and equal, discard any samples whose counts are less than this maximum. For the remaining samples, find the minimum power and then discard any samples that are more than 2 dB stronger than that minimum. Compute the average of the remaining samples. This is taken to be the Reference Level for the preamble.

I.4.1.8 Overlapping Signals and Re-Triggering

The preamble detection process is capable of processing multiple overlapped preambles, but the data block processing, which is more extensive, can only accept one signal at a time. For this reason, a re-triggering function is included. This function will reject certain preamble detections when a subsequent stronger signal is received.

One step in the re-triggering process checks for overlap by later Mode S signals having certain specific timing offsets. For example, if the subsequent signal is 1 microsecond later, then two of the preamble pulses in the later signal coincide with preamble pulses in the original signal, which can cause a problem if the later signal is stronger. The potential problem is that the stronger pulses can cause the power estimate for the first signal to be too high, and therefore prevent re-triggering. This type of problem can also occur if the timing difference is 3.5 or 4.5 microseconds. Figure I-3 illustrates the 1 microsecond overlap that motivates this test.

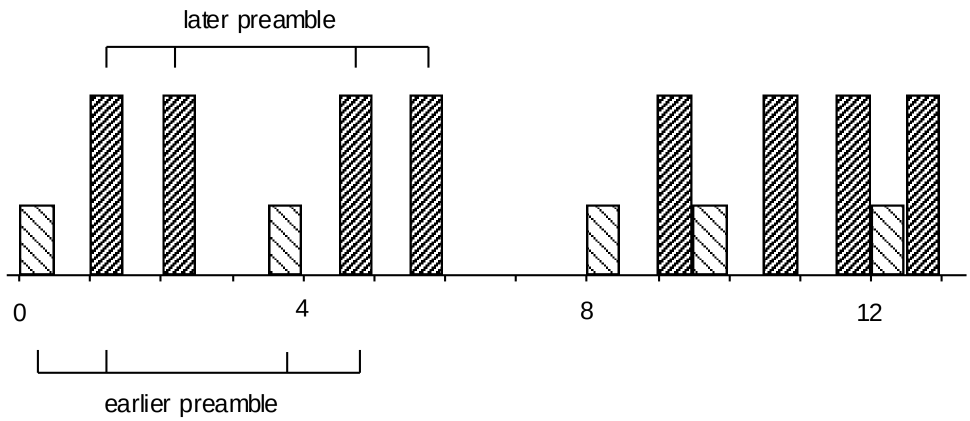


Figure I-3: Overlap of a Weak Signal by a Later and Stronger Signal

1-Microsecond Test. To counter this potential problem, the next step after preamble detection is to check for excessive power in pulse positions 1.0, 2.0, 4.5, and 5.5 microseconds after the start. For each of these pulse positions, one sample is used to estimate the power of a pulse at that time. Letting **T** = 0 denote the time one sample after the leading edge time of the first preamble pulse, then the four pulses are taken to be the samples at times **T** = 1.0, 2.0, 4.5, and 5.5 microseconds. From these four power measurements, the minimum is used to compare against the maximum of the samples at **T** = 0 and 3.5 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

3.5-microsecond test. A similar test is performed to protect against overlap by a stronger signal 3.5 microseconds later. The minimum power in samples at **T** = 3.5, 4.5, 7.0, and 8.0 is compared against the maximum of the samples at **T** = 0 and 1.0 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

4.5-microsecond test. A similar test is performed to protect against overlap by a stronger signal 4.5 microseconds later. The minimum power in samples at **T** = 4.5, 5.5, 8.0, and 9.0 microseconds is compared against the maximum of the samples at **T** = 0, 1.0, and 3.5 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

I.4.1.9 Consistent Power Test

Another test is applied to validate the preamble. This test asks whether at least two of the four preamble pulses agree in power level with the Reference Level to within +/-3 dB. If not, this preamble is rejected.

I.4.1.10 DF Validation

An additional validation is made using the first five bits in the data block. Each of the five bits is considered to consist of two chips, each of duration 0.5 microseconds. Pulse detection is carried out for the 10 chips as follows. For a particular chip, a pulse is detected if a Valid Pulse Position is found at the leading edge time for this chip or within +/-1 sample of the leading edge time. The preamble is then validated if, for each of these five bits, a pulse is detected either in the first chip or in the second chip or both and the peak amplitude of the pulse is equal to 6 dB below the preamble reference level or greater. Otherwise the preamble is rejected. The peak amplitude is determined by using the highest amplitude sample of the **M** samples that comprise the pulse (where **M** = **N** + 1 for **N** as defined in §I.4.1.3).

I.4.1.11 Re-Triggering

After a preamble is detected, the preamble detection process continues to be applied searching for later preambles. All of the steps described above are applied even when detected preambles are overlapped. If a particular preamble detection has survived these tests, its reference level and the amplitude of each of the five data pulses during DF validation is now compared against any earlier signal currently being processed. If the new signal is stronger by 3 dB or more, then the earlier signal is rejected, so that data block demodulation of the new signal can proceed. Otherwise (if an earlier signal is being processed and the new signal is not stronger by 3 dB or more), the new signal is rejected, so that the earlier signal processing can continue.

I.4.1.12 Preamble Detection Summary

Figure I-4 summarizes the preamble detection process.

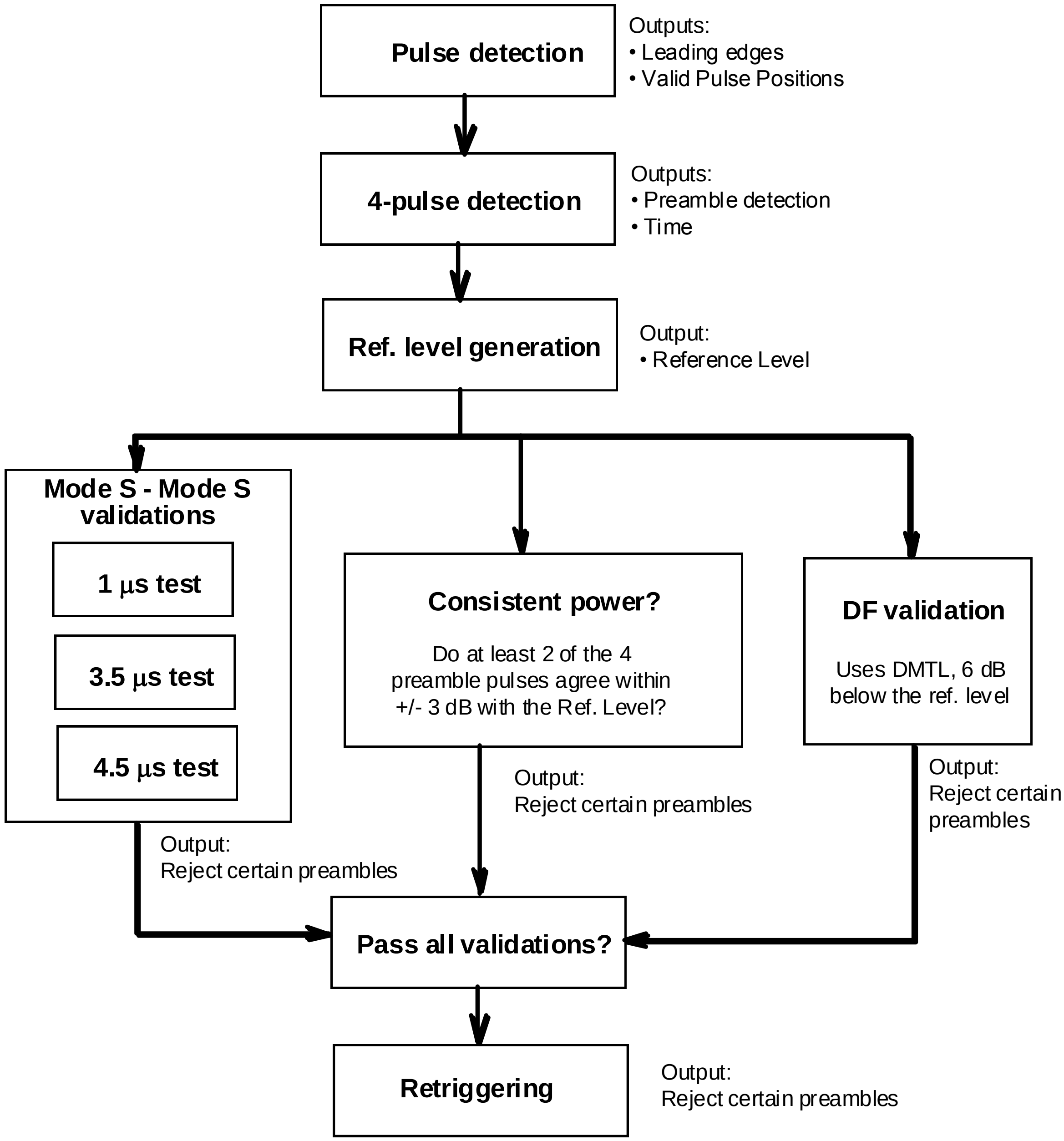


Figure I-4: Overview of Extended Squitter Preamble Detection

I.4.2 Enhanced Bit and Confidence Declaration

I.4.2.1 Overview

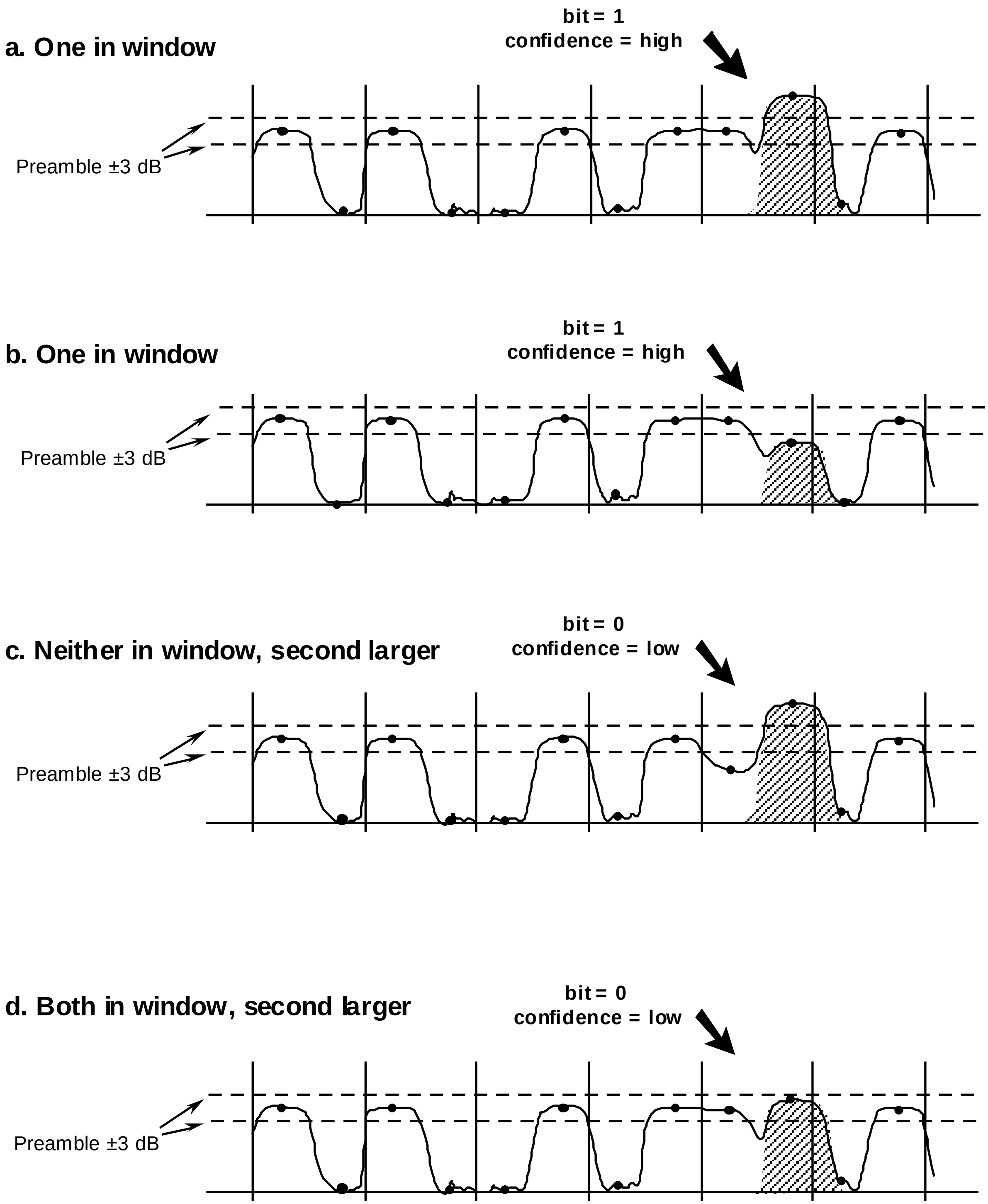
The current technique of declaring a bit based upon the higher of the two chips will generate bit errors in cases of higher level overlapping Mode A/C FRUIT (Figure I-2, part c). The use of amplitude to correlate the received pulse with the preamble pulse level will improve bit declaration accuracy. Four techniques have been investigated. One is a very simple approach that uses only the amplitude measured at the center of each chip. The remaining three use a more capable approach that takes advantage of all samples per chip that are taken to establish bit and confidence. Each of these techniques is described in the following paragraphs.

The following description of the center sample technique is intended to provide an example of processing performance needed to meet the requirements of Class A1S and A1 equipment. This description also serves as an introduction to the three more capable approaches. The center sample technique will not provide sufficient performance to meet requirements specified for Class A2 and A3 equipment in the test procedures of §2.4.4.4. The specified performance for these latter classes of equipment can only be met by an approach that performs equivalently to one of the multi-sample techniques.

I.4.2.2 Use of Center Amplitude

An improvement in the declaration of Mode S data bits can be achieved if the actual amplitudes of the center samples of the '1' and '0' chips can be measured for each data position, rather than just a comparison of which chip sample is greater. All Mode S pulses, including those of the preamble, have approximately the same level (within 1 or 2 dB). Thus if the preamble level is measured, the expected level of each data pulse will be known. Then if both center samples of a data position are above threshold, but only one is within a ±3 dB band centered at the preamble level, it would be reasonable to assume that the corresponding chip is the correct Mode S pulse location. This is illustrated in Figure I-2, part d.

Figure I-5 illustrates the new data and confidence declaration algorithms that result when the actual sample amplitudes can be measured, and both samples are above threshold. As shown in Figure I-5, a bit is high confidence when 1 and only 1 of the two samples correlate with the preamble level. The correlating sample, rather than the larger sample, is declared to be the true data value. If both samples, or neither sample, correlates with the preamble, a low confidence bit is declared. In this case, the larger sample is selected as the bit value, as in the current technique.



<u>Figure I-5:</u> Center Amplitude Bit and Confidence Declaration

The major advantage of this scheme is the significant reduction in low confidence and bit errors generated for the Mode S message. Presently, any data position with both samples above threshold is declared low confidence. This translates to a low confidence declaration whenever an above-threshold Mode A/C FRUIT overlaps a Mode S empty chip position. If the Mode A/C signal is of greater power, the bit position is declared in error.

With the center amplitude technique, a low confidence bit is declared only when the Mode A/C FRUIT is within 3 dB of the Mode S signal. Mode A/C FRUIT of either lower or higher power in general cause neither errors nor low confidence bits. Thus the region of concern for Mode A/C aircraft is reduced from all the aircraft at closer range to just those at approximately co-range. This is particularly significant when the system is attempting to listen to far-range Mode S aircraft.

It is occasionally possible for this new algorithm to produce high confidence bit errors. The most likely case occurs when two Mode A/C pulses overlay the same Mode S bit position. If one overlaps the data pulse, and drives its sample out of the preamble window, then an error will result if the other Mode A/C pulse lands on the other chip and its amplitude is within the preamble window. Such occurrences will in general create a rejected message, rather than an undetected error.

I.4.2.3 Use of Multiple Amplitude Samples

The above amplitude data declaration approach can be improved if all 10 samples (5 per chip) that are taken for each Mode S bit position are utilized in the decision process. In particular, the event of both center samples within the preamble window can often be resolved. For example, consider the typical such situation depicted in Figure I-2, part e. Although both center samples are within the window, the fact that the earlier chip has all samples within the window, whereas the later chip has several samples below the window suggests that the signal is present in the earlier chip. This error situation can often be rectified when all 10 samples are examined. Also, in some cases when an interference pulse overlaps a signal pulse, the small frequency difference will produce variations in amplitude, whereas the signal by itself would be more constant, and such patterns can be useful in declaring the bit and confidence.

I.4.2.3.1 Baseline Multi-Sample Technique

The multi-sample enhanced bit and confidence declaration technique makes use of all 10 samples for each Mode S bit position to determine the bit and confidence values. Sample amplitudes in each chip are compared to the amplitude reference level established by the preamble to quantify the number of samples in each chip that:

(a) match the preamble amplitude indicating the presence of a pulse, or

(b) are significantly lower in amplitude indicating a lack of transmitted energy.

The first step is to establish an amplitude window that will include samples that are within +/- 3 dB of the preamble reference level and a minimum amplitude threshold set to 6 dB below the reference level. Samples that fall within the window are considered to match the preamble and samples that are below the minimum threshold are considered to indicate a lack of transmitted energy. The samples are categorized as follows:

A: within the +/- 3 dB preamble window

B: below threshold (6 dB or more below the preamble)

The second step is to count the number of samples in each chip that are of each category. Less weight is given to the samples near the transitional areas of each chip (the transitional samples are the first and last samples of each chip). To facilitate this, samples other than those at each end will count double. Therefore, with weighting factored in, and a 10 MHz sampling rate, the counts for each category will range from 0 to 8 for each chip (1 sample at each end + 3 samples in-between x 2). The four counts are summarized as follows:

1ChipTypeA = #of weighted samples in the 1 chip of type A (Match Preamble)

1ChipTypeB = #of weighted samples in the 1 chip of type B (Lack energy)

0ChipTypeA = #of weighted samples in the 0 chip of type A (Match Preamble)

0ChipTypeB = #of weighted samples in the 0 chip of type B (Lack Energy)

Next, two equations using the above counts will produce two scores that indicate how well the sample pattern matches a transmitted 0 and how well the sample pattern matches a transmitted 1. The equations are as follows:

1Score = 1ChipTypeA – 0ChipTypeA + 0ChipTypeB – 1ChipTypeB

0Score = 0ChipTypeA – 1ChipTypeA + 1ChipTypeB – 0ChipTypeB

The highest score determines the bit value. In the case of a tie, the bit defaults to zero (0). If the difference is 3 or more the bit is high confidence. The confidence threshold of 3 was determined by testing the algorithm with a 10 MHz sampling rate with thousands of iterations with a high FRUIT rate. If the algorithm is applied with a different sampling rate, the appropriate confidence threshold may need to be determined under similar test conditions.

I.4.2.3.2 Multi-Sample Technique With Full Table Lookup

To take advantage of the differences between a pure signal and a combination of signal plus interference, a technique was developed based on a lookup table, whose contents are derived from many runs of a simulation. Specifically, each of the 10 samples is quantized into four levels:

0: below threshold (-6 dB relative to the preamble)

1: above threshold but below the +/- 3 dB preamble window

2: within the +/- 3 dB preamble window

3: above the +/- 3 dB preamble window

Since there are 10 samples, with 4 possible values each, a Mode S data position can have 4^{10} = 1048576 (1M) different sample patterns. Two 1-bit tables, each stored in a 1M x 1 ROM, are defined over the set of patterns: the first declaring the bit position to be a '1' or

'0', the second high or low confidence. Once the pattern existing for a given bit is determined, two table lookups supply the proper declaration. If higher sampling rates are used, the number of sample patterns and the table size will increase exponentially.

These tables are generated by running millions of simulations of Mode S messages in 40,000 FRUIT per second environments. For each bit of each trial, the pattern and the correct Mode S bit value are noted. The result could be, for example, 5876 examples of pattern 16453, of which 5477 occurred when the Mode S bit was a “1.” The table values are then defined as follows, assuming an "uncertainty parameter" value of 10%:

H1: 90% or more of the samples occurred when the bit was a '1'

L1: 50% - 90% of the samples occurred when the bit was a '1'

L0: 10% - 50% of the samples occurred when the bit was a '1'

H0: 10% or fewer of the samples occurred when the bit was a '1'.

Since pulse shapes are critical to this method, live data verification of the table entries is required to establish these values.

I.4.2.3.3 Multi-Sample Technique With Reduced Table Lookup

The above 10 sample approach requires lookup tables of size 1M, adding cost to the hardware implementation of the decoder. A variation of this method that only requires tables of size 1K, called the 5-5 approach, has been designed to reduce this expense.

The 5-5 method forms two estimates of the bit data and confidence values, one using the odd samples (1-3-5-7-9) and the other using the even samples (2-4-6-8-10); the final decision is then a combination of the individual estimates. Since each set includes samples in both chip positions, pattern matching is still possible, although the fineness of the pattern variation is cut in half. Since only 5 samples are in each set, and each sample is quantized to the same 4 levels as above, $4^5 = 1024$ patterns are possible for each set.

To counteract the loss of resolution, and to aid in the combining operation, 3 levels of confidence (high, medium, and low) are defined for each pattern. Following the simulation generation scheme described above, the table values are defined as follows:

H1: 90% or more of the samples occurred when the bit was a '1'

M1: 70% - 90% of the samples occurred when the bit was a '1'

L1: 50% - 70% of the samples occurred when the bit was a '1'

L0: 30% - 50% of the samples occurred when the bit was a '1'

M0: 10% - 30% of the samples occurred when the bit was a '1'

H0: 10% or fewer of the samples occurred when the bit was a '1'.

The values of 10% and 30% are parameters; the value of 30% was selected to provide the performance discussed below. Since 3 confidence levels now exist, the confidence lookup table for each sample set is sized 1024x2. The total table requirement for data and confidence, for the two sample sets, is thus 1024x6.

Once the values and confidences are determined for each set of samples, odd and even, the composite values actually declared for the bit are found according to Table I-1.

Table I-1: Combining Odd and Even Outputs

Odd	Even					
	H1	M1	L1	H0	M0	L0
H1	H1	H1	H1	L0	H1	H1
M1	H1	H1	L1	H0	L0	L1
L1	H1	L1	L1	H0	L0	L0
H0	L0	H0	H0	H0	H0	H0
M0	H1	L0	L0	H0	H0	L0
L0	H1	L1	L0	H0	L0	L0

Note that if either sample set is high confidence, that set's data value rules unless the samples conflict and are both high confidence. Also notice that two agreeing medium confidence samples produce a high confidence result. With the parameter for medium confidence set at 30%, the probability of error for medium confidence agreement is 0.3 x 0.3 = 0.1, which matches the 10 sample probability of error for a high confidence decision. Finally, when the sample decisions conflict at the same confidence level, a low confidence 0 is declared for lack of a better estimate.

If a sampling rate other than 10 MHz is used, the number of samples from the odd and even samples and the resulting table sizes will be adjusted accordingly. For example, if a 8 MHz sampling rate is used, there are 4 samples in each set, and each sample is quantized to the same 4 levels as above, $4^4 = 256$ patterns are possible for each set. The total table requirement for data and confidence, for the two sample sets, is thus 256x6. If a 16 MHz sampling rate is used, there are 8 samples in each set, and each sample is quantized to the same 4 levels as above, $4^8 = 65,536$ (64K) patterns are possible for each set. The total table requirement for data and confidence, for the two sample sets, is thus 64Kx6. Once the values and confidences are determined for each set of samples, odd and even, the composite values are declared according to Table I-1 independent of the sampling rate.

I.4.3 Enhanced Error Detection and Correction Techniques

I.4.3.1 Overview

Three new error detection/correction techniques have been developed. The first, termed the "Conservative" technique is a variation on the current Sliding Window technique, intended to reduce the undetected error rate. The second, termed the "Whole Message" technique, models the effect of whole Mode A/C FRUIT on the bit and confidence declarations. The third, termed the "Brute Force" technique, performs a bounded exhaustive search of all combinations of bit reversals for low confidence bits. The following sections describe these techniques in more detail.

I.4.3.2 Conservative Technique

The sliding window technique is suitable for the low FRUIT environments of a rotating beam antenna (long range, narrow beam) or a TCAS (omni-directional, short range). However, the FRUIT environment for the long-range air-to-air application (which uses omni-directional antennas) may be very severe and therefore, the sliding window technique cannot be used because of undetected error considerations.

For the very severe FRUIT environments, a simpler approach, known as the conservative technique is used. Using this technique, error correction is only attempted if all of the low confidence bits in the message are within a 24-bit window, and there are no more than 12 low confidence bits. This constraint limits the application of error correction to signals that nominally had only a single overlapping stronger Mode A/C FRUIT. This is a conservative approach in that the conditions for attempting error correction are much more restrictive than with sliding window. It produces a lower level of successful error correction since it does not attempt to correct messages with multiple Mode A/C overlaps. However, it produces a very low undetected error rate, as intended.

If the conditions for applying the conservative technique are met, the error syndrome is generated for the window position and (as for the sliding window technique) a check is made to see if the ones (1) in the error syndrome correspond to low confidence bits in the window. If so, error correction is accomplished. If not, the process is terminated.

If the low confidence bits span less than 24-bits, more than one window could be defined to span them. This will not effect the error correction action, since regardless of the 24-bit window selected to span the low confidence bits, the ones (1) in the error syndrome will identify the same message bits. That is, if the window is moved one bit, the error syndrome will shift by one bit.

Note that in the above description, there is only one possible successful error correction possibility. Regardless of the specific 24-bit window position, the same message bits are identified. All of the bits corresponding to a one (1) in the error syndrome must be complemented. This can only happen if they are all low confidence. Therefore, there is at most, one correctable error pattern that can be achieved with the conservative error correction technique.

I.4.3.3 Whole Message Error Detection and Correction Technique

The limitation of the current error correction technique described in I.3.3 of being able to handle only a single overlapping Mode A/C FRUIT has led to the development of the Whole Message error correction technique, which can be applied when the Conservative technique has failed. This technique is designed to handle up to five overlapping FRUIT, provided they do not overlap each other, hence creating "individual interference regions." This technique is applicable only when the center sampling technique is used (§I.4.2.2).

As described in §I.3.2, the correctness of low confidence bits depend upon the amplitude of the Mode A/C interference relative to the Mode S squitter: if the Mode A/C FRUIT is stronger than the Mode S signal, any low confidence bit will usually be declared in error, while if the Mode S signal is stronger, any low confidence bit will usually be declared correctly. This observation leads to the following hypothesis, which serves as the basis of the Whole Message error correction routine:

For a given Mode A/C interference region, either all low confidence bits will be correct, or all low confidence bits will be wrong.

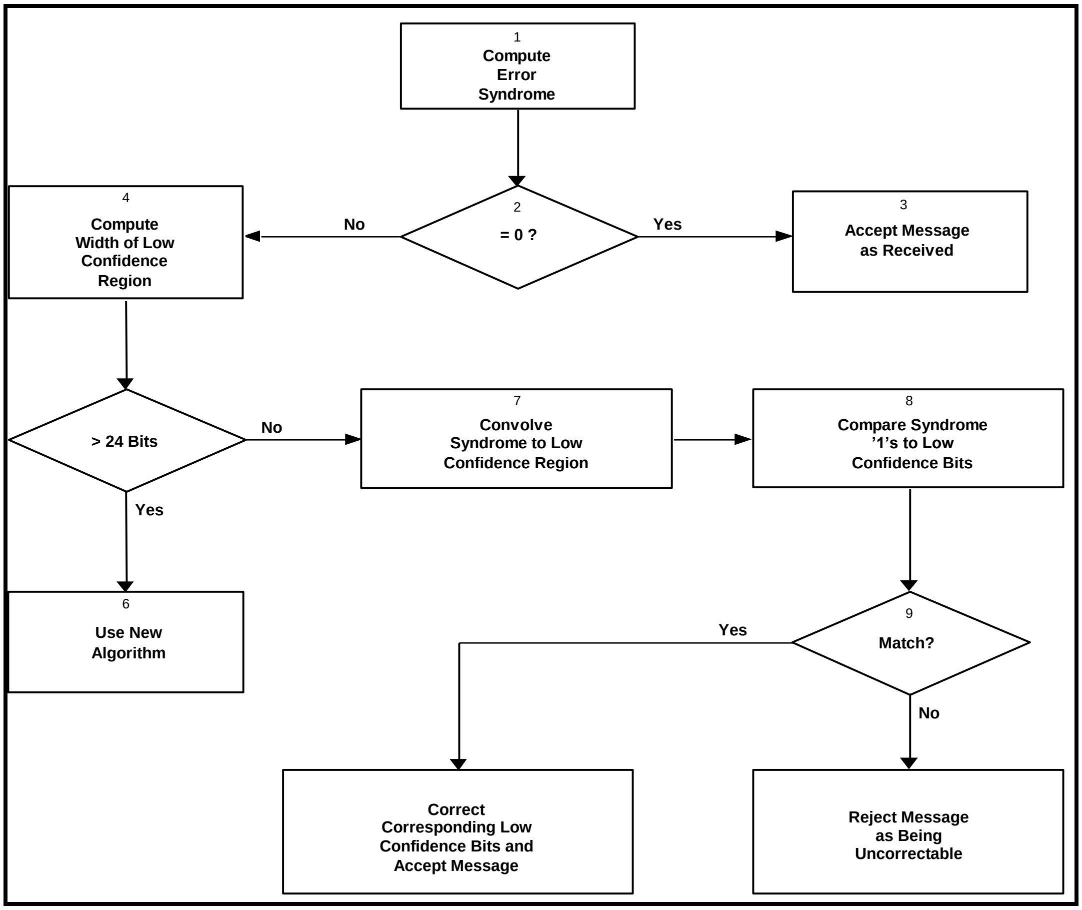
Although this hypothesis is generally correct, it should be noted that three effects can lead to its violation:

1. If the interfering Mode A/C FRUIT is at approximately the same power level as the Mode S signal, or

2. If the interfering Mode A/C FRUIT pulses are wider than 0.50 microseconds (the spec allows up to 0.55 microseconds, and some out-of-spec transponders even go beyond this value), or

3. If the Mode S signal is near enough to the noise level for noise to corrupt some of the samples.

The Whole Message algorithm attempts to divide the Mode S message into disjoint 24-bit regions, one for each presumed Mode A/C interfering FRUIT. Then the syndrome of each region, assuming all bits to be in error, is generated (see below in §I.4.3.4 for an explanation of syndrome generation for bit sets). Finally, all possible combinations of syndromes are considered. If one and only one combination matches the Mode S syndrome, all low confidence bits within the interference regions corresponding to the winning combination are reversed. Flowcharts for the Whole Message error correction technique are presented in Figure I-6 and Figure I-7. Figure I-8 presents an example of the application of this method.



<u>Figure I-6:</u> Whole Message Top Level Error Correction Algorithm

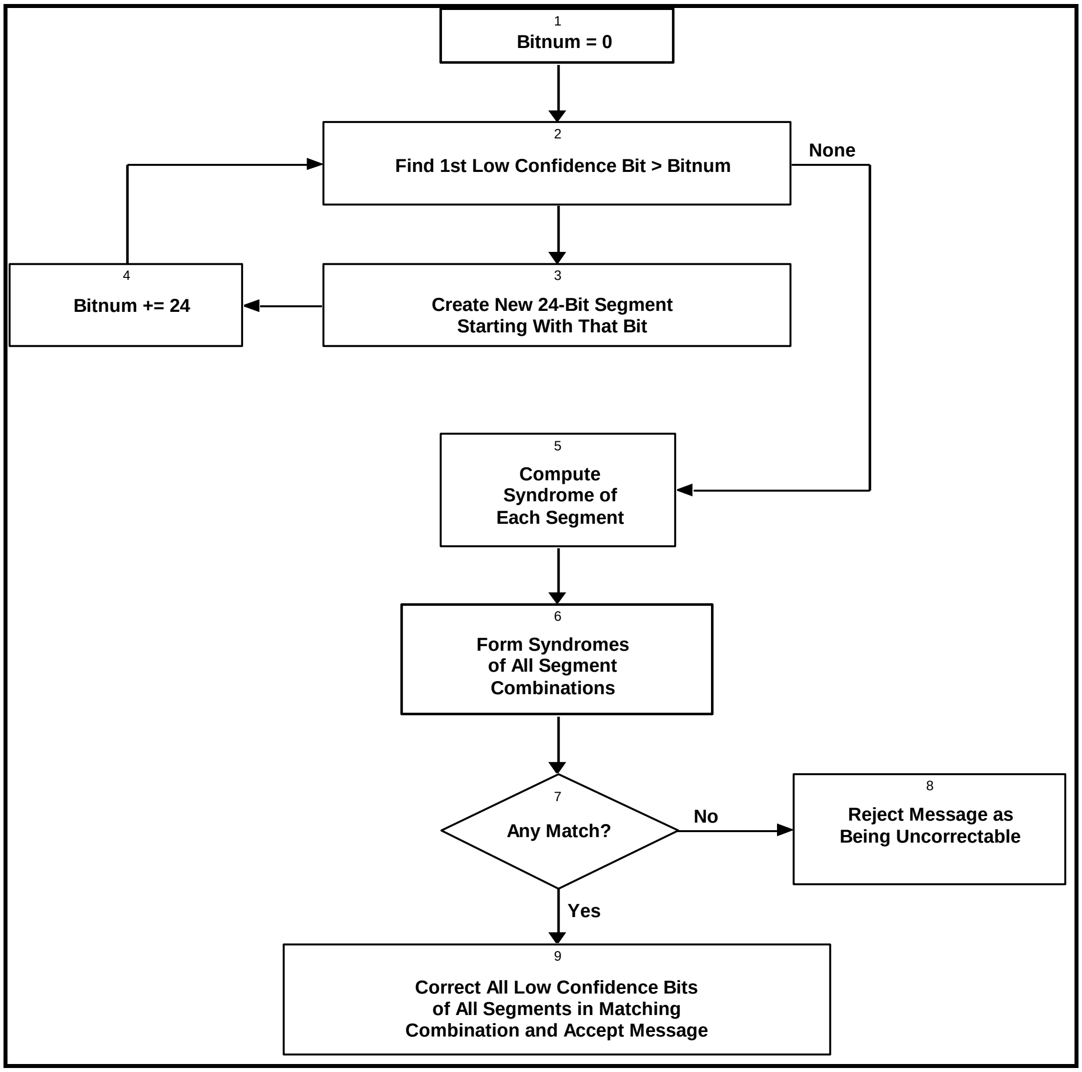


Figure I-7: Whole Message Detailed Error Correction Algorithm

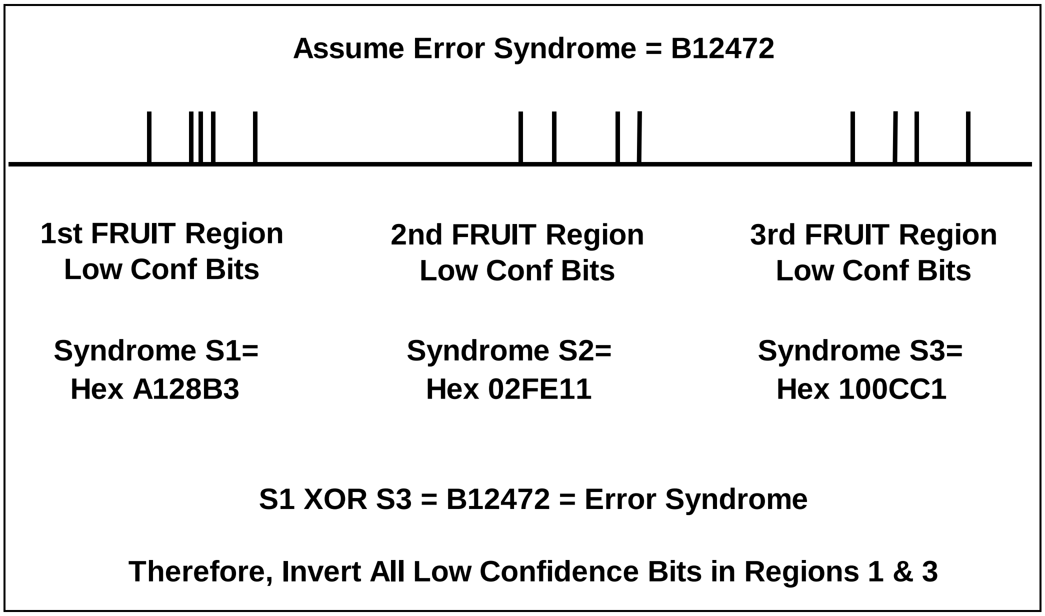
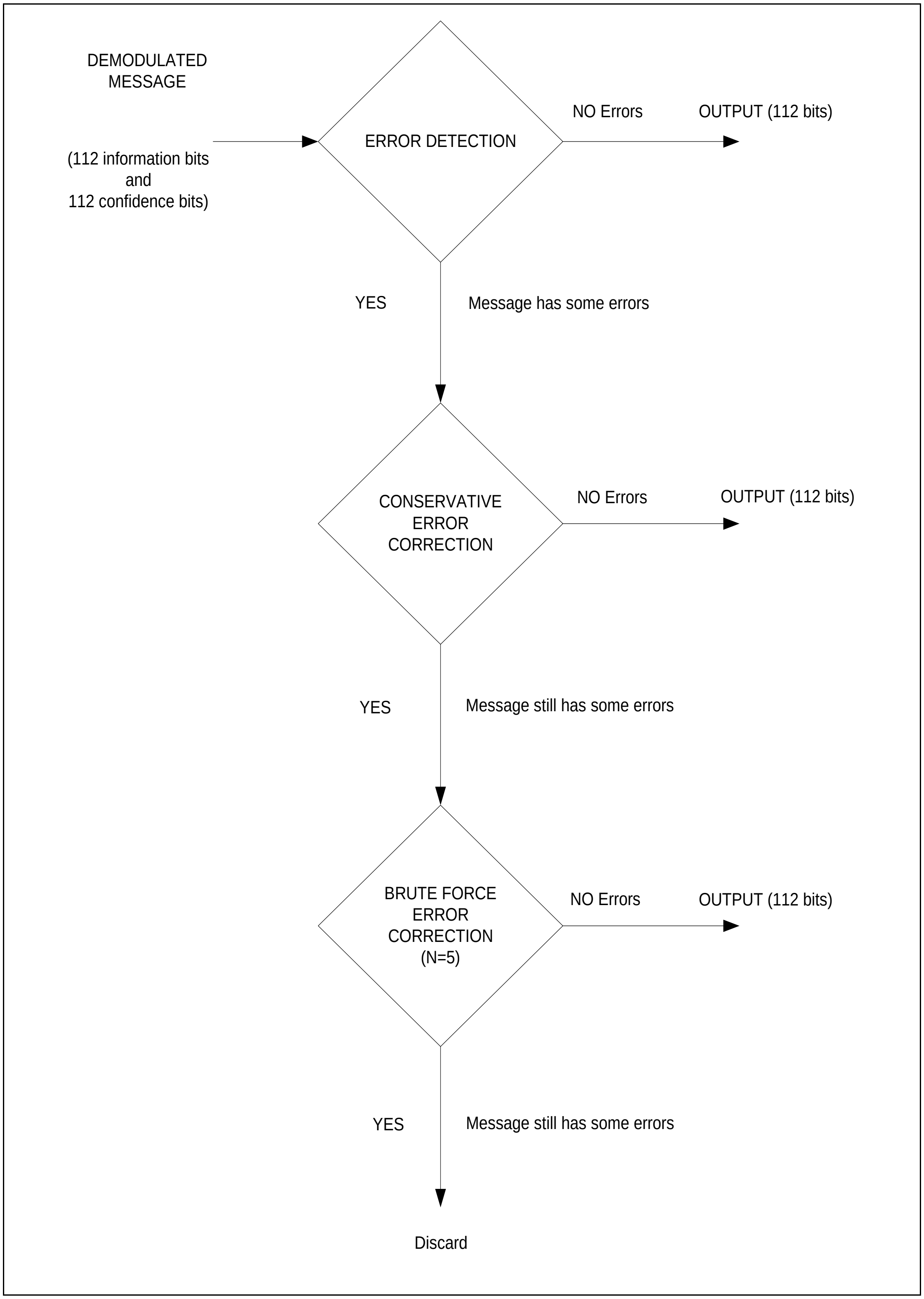


Figure I-8: **Whole Message Error Correction Example**

I.4.3.4 Brute Force Error Correction Technique

If the bit declaration algorithm has performed its function properly, all errors in Mode S data values will reside in bits declared low confidence. If this is true, a simple approach to error correction is to try all possible combination of low confidence bits, and accept the set that matches the error syndrome (provided only one success is discovered). For obvious reasons, this method has been named the Brute Force Technique. It is applicable to any method of data and confidence declaration, with or without amplitude. As illustrated in Figure I-9, Brute Force error correction is applied after the other techniques have failed.



<u>Figure I-9:</u> Error Detection and Correction

Implementation of this technique depends upon the fact that each Mode S bit position corresponds to a unique syndrome, and that sets of bits produce a syndrome that is the exclusive OR of all individual bit syndromes. For example, if bit 1 is the only bit declared in error, the error syndrome at the receiver will be hex 3935EA, while bit 31 produces hex FDB444, and bit 111 has syndrome hex 000002. Thus if those three bits are all declared in error, the error syndrome will be calculated to be hex C481AC. The table of individual bit syndromes is pre-calculated and stored in the receiver.

It is possible for two or more subsets of the low confidence bits to match the syndrome. In such cases, the message is rejected, and no harm is done. However, if a high confidence bit has been declared in error, and a single subset of the low confidence bits matches the syndrome, the message will be "corrected" to the wrong message, producing an undetected error. (If no subset matches the syndrome, it must be true that a high confidence bit error has been made, and the message is rejected.)

Clearly, for processing time and error bounding reasons, the maximum number of low confidence bits to process must be limited. The number of cases to consider is given by 2^n. If **n** low confidence bits exist for a message; this grows exponentially with **n** (32 at **n** = 5, 4096 at **n** = 12). The undetected error rate is proportional to the number of cases, and thus also grows exponentially with **n**. Fortunately, the Hamming distance of 6 for the Mode S parity code implies that undetected errors are essentially zero if **n**</=5 is enforced. For this reason, a value of **n** = 5 has been used in the development of the brute force algorithm.

I.5 Improved Reception Performance in a High Fruit Environment

For improved reception performance in a high FRUIT environment, the optimum configuration has been found to be:

1. Enhanced preamble detection (§I.4.1)

2. Bit and confidence declaration based on the Baseline Multi-sample Technique (§I.4.2.3.1)

3. Error detection using the Mode S 24-bit CRC technique (Ref. RTCA DO-185B)

4. First pass error correction using the conservative technique (§I.4.3.2)

5. Second pass error correction using the brute force technique with n=5 (§I.4.3.4)

The process proceeds as follows. Preamble detection and bit and confidence declaration are performed. Next, Mode S error detection is applied. If the message passes, the process ends, and the message is delivered. If an error is detected, then conservative error correction is applied, and if a correction results, then the process ends, and the message is delivered. If the constraint for conservative correction is not satisfied, then the brute force technique is applied.

The above configuration was used as the basis for the performance required for enhanced squitter reception as specified in §2.2.4.4.

I.6 Summary

New techniques have been developed for enhancing reception of Extended Squitters in environments of high interference. The new techniques include improvements in preamble detection, improvements in declaration of information bits and confidence bits within the squitter message, and improvements in error detection/correction.

These developments were originally carried out using pulse-level simulation to assess the resulting performance. Subsequently flight tests have been conducted using these techniques, making comparisons relative to the current techniques. Both the simulation and flight test results indicate that substantial improvements in performance are achievable using these techniques when operating in an environment of high interference.

APPENDIX I REFERENCES

I-1. J. L. Gertz, "Fundamentals of Mode S Parity Coding," M I T Lincoln Laboratory Project Report ATC-117, April 1984.

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Appendix J

Determining The Navigation Accuracy Category For Velocity (NAC_V)

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J Determining the Navigation Accuracy Category for Velocity (NAC_V)

J.1 Purpose and Scope

This Appendix describes the manner in which GNSS position sources, which do not output velocity accuracy, can be characterized so that a velocity accuracy value associated with the position source can be input into ADS-B equipment as part of the installation process. Section J.4 discusses the expected velocity accuracy performance of GNSS during stable flight (the NAC_V is specified in such a manner that it needs to accommodate velocity errors during normal maneuvers of the aircraft).

J.2 Rationale for Table 2-25, "Determining NAC_V Based on Position Source Declared Horizontal Velocity Error

Until recently, acceptable means to substantiate a navigation source's capability to support NAC_V were not clearly established in Global Positioning System (GPS) sensor minimum operational performance standards. In light of this deficiency, a "best-method" was originally established in §2.2.3.2.6.1.5 of RTCA DO-260A (ADS-B Version Number = 1) to utilize the HFOM/VFOM quality indicator as a surrogate for setting the NAC_V value. The rationale for this method was documented in Appendix J of DO-260A. However, the use of HFOM/VFOM to set NAC_V was not considered acceptable, since it does not provide an appropriate indication of the true horizontal velocity error as established by the position sensor manufacturer.

To remedy this deficiency, the FAA requested RTCA SC-159 to develop test procedures for a velocity accuracy test to characterize the 95% horizontal and 95% vertical velocity accuracies during normal maneuvers as specified in RTCA/DO-229D and RTCA/DO-253B receiver MOPS. These tests can be used to substantiate Global Positioning System (GPS), GPS/Space-Based Augmentation System (SBAS), or GPS/Ground-Based Augmentation System (GBAS) equipment to support an ADS-B NAC_V =1 requirement of horizontal velocity error less than 10 meters/second (95th percentile with HDOP of 1.5 or less) and vertical velocity error less than 50 feet/second (95th percentile, with VDOP of 3.0 or less). Additional test procedures were developed to substantiate equipment that supports a NAC_V =2 requirement of horizontal velocity error less than 3 meters/second and vertical velocity error less than 15 feet/second. However, these tests are not adequate for demonstrating more stringent ADS-B NAC_V levels (i.e., NAC_V = 3, or greater) – such tests are expected to be developed as more demanding ADS-B applications mature.

Navigation equipment manufacturers can submit the results of this testing with their TSO application or as additional information if they have already received TSO approval, for acceptance as approved data. Manufacturers of navigation equipment that pass these tests should document their equipment's 95% figure of merit velocity accuracy in their installation manual (or provide a velocity accuracy quality metric output for direct use by the ADS-B equipment.) The velocity output has no explicit integrity beyond the 95% figure of merit for the stated HDOP and VDOP.

Note: *FAA AIR-100 memorandum dated October 10, 2008 serves as an interim reference describing testing procedures acceptable to the FAA until the procedures are incorporated into more formal GPS MOPS guidance material.*

J.3 Tests to Determine Velocity Accuracy for Support Setting NAC_V = 1 or 2

The ADS-B installations with a position source capable of providing velocity accuracy should have the NAC_V derived from the position source, and the velocity accuracy should be validated during the position source manufacturer's certification testing. The following procedures, developed by RTCA SC-159, are one means of accomplishing this testing.

The purpose of GNSS velocity accuracy test is to characterize the 95% horizontal and 95% vertical velocity accuracies during normal maneuvers as specified in RTCA/DO-229D and RTCA/DO-253B receiver MOPS for equipment intended to support either NAC_V =1 or NACV = 2. Test procedures for higher levels are expected to be developed as more demanding ADS-B applications mature.

The tests to verify velocity accuracy performance shall be run for each of the scenarios described below for all operating modes of the receiver where a valid position and/or velocity could be output by the receiver.

Note: *It is possible that a given receiver may use a different velocity algorithm when computing an un-augmented GPS position solution versus computing a solution augmented with differential corrections. In that case, this test must be repeated for both the augmented and un-augmented modes of operation. Even in the case where the velocity algorithm is the same whether in un-augmented or augmented mode, there are still enough variables like the software path, inputs, outputs etc., that it is required to repeat the test. However it is not required to repeat the test for different sub-modes of an un-augmented or augmented mode where the inputs, velocity algorithm and outputs are the same.*

J.3.1 Horizontal Velocity Accuracy Test Conditions Commensurate with NAC_V = 1

1. Ensure the simulator scenario has enough GPS satellites to provide a HDOP of 1.5 or less.

2. One satellite shall set at maximum power (including maximum combined satellite and aircraft antenna gain), and the other satellites shall be set at minimum power (including minimum antenna gain).

3. Broadband GNSS test noise ($I_{GNSS,Test}$) of spectral density as defined in DO-229D accuracy test §2.5.8. Broadband external interference ($I_{ext,test}$) and thermal noise contribution from the sky and the antenna ($N_{sky,antenna}$) shall be simulated.

4. The airborne equipment shall be initialized with the appropriate position and time. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting the test.

5. Platform Dynamics for the horizontal velocity accuracy test shall be as defined in Table J-1.

Table J-1: Platform Dynamics for the Horizontal Velocity Accuracy Test

Time (s)		**Dynamics**	**Start Jerk (g/s)**				**End Jerk (g/s)**			
From	**To**		**North**	**East**	**Down**	**Total**	**North**	**East**	**Down**	**Total**
0	T	Static	0	0	0	0	0	0	0	0
T+1	T+71	0.58g longitudinal acceleration to 411 m/s	0.xx *Note 1*	0.xx *Note 1*	0	0.25	0.xx *Note 1*	0.xx *Note 1*	0	0.25
T+72	T+129	Straight un-accelerated flight	0	0	0	0	0	0	0	0
T+130	T+194	-0.45g longitudinal acceleration to 125 m/s	0.xx *Note 1*	0.xx *Note 1*	0	0.2	0.xx *Note 1*	0.xx *Note 1*	0	0.2
T+195	T+254	Straight un-accelerated flight	0	0	0	0	0	0	0	0
T+255	T+325	turn 180° with 0.58g lateral acceleration	0.xx *Note 1*	0.xx *Note 1*	0	0.25	0.xx *Note 1*	0.xx *Note 1*	0	0.25
T+326	T+420	Straight un-accelerated flight	0	0	0	0	0	0	0	0

Notes:

1. *The components of the jerk in the North and East direction depend on the heading chosen in the scenario. The total jerk is the not to exceed vector combination of north, east, and down jerk components. The maximum total jerk to quickly achieve the desired dynamics should be used, but the jerk should not exceed the normal maneuver total jerk requirement of 0.25g/s.*
2. *The actual times may vary based on the simulator scenario control settings.*

6. Signal and RF Interference conditions can be modified during static period to aid acquisition. Ensure the receiver enters the desired Operation mode before dynamics and appropriate signal and interference conditions are applied.

7. Use the simulator velocity truth data ($V_i^{east\_truth}$, $V_i^{north\_truth}$) and the GNSS receiver velocity data (V_i^{east}, V_i^{north}) to determine the horizontal velocity error after the GNSS receiver has entered the desired Navigation mode with the specified signal and RF Interference conditions:

$$h_i = \sqrt{(V_i^{east\_truth} - V_i^{east})^2 + (V_i^{north\_truth} - V_i^{north})^2}$$

J.3.1.1 Pass/Fail Determination

The 95% Horizontal Velocity accuracy statistic shall be computed using the formula given below. The equipment shall pass if the statistic is less than 10 m/s.

$$2 * \sqrt{\frac{\sum_{i=1}^{N} \left(\frac{1.5 (h_i)}{HDOP_i} \right)^2}{N}}$$

Where:

h_i – is the horizontal velocity error (m/sec)

N – Number of sample points used

For this test, the number of samples shall include all samples where the receiver is in the desired Navigation mode and when in motion.

Note: *The minimum of samples is 420 for 1 Hz solution and 2100 for 5 Hz solution (i.e., 5* 420).*

The receiver velocity data and the $HFOM_V$ data shall be used to determine the percentage of samples bounded by the $HFOM_V$ as shown below. The test passes only if $TS_{h,b}$ is greater than or equal to 0.95.

$$TS_{h,b} = \frac{1}{N}\sum_{i=1}^{N} b_{h,i}$$

$$N = \text{number of samples}$$

$$b_{h,i} = \begin{cases} 1 & h_i \le HFOM_V \\ 0 & h_i > HFOM_V \end{cases}$$

J.3.1.2 Vertical Velocity Accuracy Test Conditions Commensurate with NAC_V = 1

1. Ensure the simulator scenario has enough GPS satellites to provide a VDOP of 3.0 or less.

2. One satellite shall set at maximum power (including maximum combined satellite and aircraft antenna gain), and the other satellites shall be set at minimum power (including minimum antenna gain).

3. Broadband GNSS test noise ($I_{GNSS,Test}$) of spectral density as defined in RTCA DO-229D accuracy test §2.5.8. Broadband external interference ($I_{ext,test}$) and thermal noise contribution from the sky and the antenna ($N_{sky,antenna}$) shall be simulated.

4. The airborne equipment shall be initialized with the appropriate position and time. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting the test.

5. Platform Dynamics for the vertical velocity accuracy test shall be as defined in Table J-2.

Table J-2: Platform Dynamics for the Vertical Velocity Accuracy Test

Time (s)		Dynamics	Start Jerk (g/s)				End Jerk (g/s)			
From	**To**		**North**	**East**	**Down**	**Total**	**North**	**East**	**Down**	**Total**
0	T	Static	0	0	0	0	0	0	0	0
T+1	T+71	0.58g longitudinal acceleration to 411 m/s	0.xx *Note 1*	0.xx *Note 1*	0	0.25	0.xx *Note 1*	0.xx *Note 1*	0	0.25
T+72	T+130	Straight and level un-accelerated flight	0	0	0	0	0	0	0	0
T+131	T+131+X	Climb, increasing the vertical climb rate from 0 to 21 m/s, then decrease the rate back to 0 m/s and repeat this increasing and decreasing pattern until the time out.	0	0	0.xx *Note 1*	0.25	0	0	0.xx *Note 1*	0.25
T+132+X	T+192+X	Straight and level un-accelerated flight	0	0	0	0	0	0	0	0
T+193+X	T+193+2X	Descend, increasing the vertical descent rate from 0 to 21 m/s, then decrease the rate back to 0 m/s and repeat this increasing and decreasing pattern until the time out.	0	0	0.xx *Note 1*	0.25	0	0	0.xx *Note 1*	0.25
T+194+2X	T+274+2X	Straight and level un-accelerated flight	0	0	0	0	0	0	0	0

Notes:

1. *The components of the jerk in the North and East direction depend on the heading chosen in the scenario. The total jerk is the not to exceed vector combination of north, east, and down jerk components. The maximum total jerk to quickly achieve the desired dynamics should be used, but the jerk should not exceed the normal maneuver total jerk requirement of 0.25g/s.*
2. *The actual times may vary based on the simulator scenario control settings.*
3. *The value of X must be at least 63 seconds to have enough samples during vertical acceleration.*

6. Signal and RF Interference conditions can be modified during static period to aid acquisition. Ensure the receiver enters the desired Operation mode before dynamics and appropriate signal and interference conditions are applied.

7. Use the simulator velocity truth data ($V_i^{vertical\_truth}$) and the GNSS receiver velocity data ($V_i^{vertical}$) to determine the vertical velocity error (v_i) after the GNSS receiver has entered the desired Navigation mode with the specified signal and RF Interference conditions: $v_i = | V_i^{vertical\_truth} - V_i^{vertical} |$.

J.3.1.3 Pass/Fail Determination

The 95% Vertical Velocity accuracy statistic shall be computed using the formula given below. The equipment shall be considered pass only if the statistic is less than 50 ft/s.

$$2 * \sqrt{\frac{\sum_{i=1}^{N} \left(\frac{3(v_i)}{VDOP_i} \right)^2}{N}}$$

Where:

v_i - is the vertical velocity error (ft/sec)

N – Number of sample points used

For this test, the number of samples shall include all samples where the receiver is in the desired Operation mode.

Note: *The minimum of samples is 420 for 1 Hz solution and 2100 for 5 Hz solution.*

The receiver velocity data and the $VFOM_V$ data shall determine the percentage of samples bounded by the $VFOM_V$ as shown below. The test passes if is greater than or equal to 0.95.

$$TS_{v,b} = \frac{1}{N} \sum_{i=1}^{N} b_{v,i}$$

$$N = \text{number of samples}$$

$$b_{v,i} = \begin{cases} 1 & v_i \le VFOM_V \\ 0 & v_i > VFOM_V \end{cases}$$

J.3.2 Additional Tests to Demonstrate Accuracy Commensurate with NAC_V = 2

The following procedure is one acceptable means for equipment capable of better accuracy performance to demonstrate compliance with the horizontal velocity error requirement of less than 3 m/s.

1. Run the scenario in Table J-1 with all satellites set at high power and no RF interference.

2. This accuracy evaluation shall only include those data samples collected during the acceleration period.

3. Find the particular h_i (noted as T_{acc}) so that 95% of h_i samples are less than or equal to T_{acc} .

4. Re-run the scenario in Table J-1 with the same satellite and RF interference conditions as the 10 m/s (NAC_V=1) test.

5. This time only the data samples during the non-acceleration period with the specified signal and RF Interference conditions are used.

6. Compute $T_{non\_acc} = 2 * \sqrt{\frac{\sum_{i=1}^{N_{non\_acc}} \left(\frac{1.5 (\epsilon_{i\_non\_acc})}{HDOP_{i\_non\_acc}} \right)^2}{N_{non\_acc}}}$

   Where $HDOP_{i\_non\_acc}$ and N_{non_acc} are the HDOP values for each sample *i* and the total number of samples (non-acceleration period), respectively.

7. The test passes only if $T_{acc} + T_{non\_acc}$ is less than 3 m/s.

8. The velocity FOM is evaluated in the same way as for the 10 m/s test, i.e., the samples during acceleration and non-acceleration periods of the above 2 runs are evaluated together against the 0.95 threshold.

The vertical velocity requirement of 15 ft/s should be tested using the exact same philosophy as the test of 3 m/s above but with the scenario in Table J-2.

J.4 Expected GNSS Velocity Accuracy in Stable Flight

Although NAC_V will accommodate derived velocity lags at turn rates of up to 0.5g, it over-bounds by a substantial amount the 95% velocity error of about 0.2 m/s per axis which should be expected in stable flight[1]. This conservative bounding of expected GPS velocity quality has led application designers and simulators to incorrect impressions of the potential value of the instantaneous velocity provided in the GPS state vector.

Velocity lag errors have long been an issue in the use of ATC automation derived velocity with radars as the sensor input. Assurance that better velocity is available when flight dynamics permit is obtained by separately specifying acceptable ATC tracker errors for stable and turning tracks. The STARS requirement on estimated heading error is indicated by values in Table Q-3.

Table J-3: Heading Accuracy (RMS degrees)

Speed (knots)	**Stable Flight Heading error**	**Transient Tracks Heading error**
100	12	51
250	6	30
400	3	31

[1] NAVSTAR GPS User Equipment Introduction, 1996, Page 3-7 and "Measurement of Aircraft Velocity Using GPS", Institute of Electronics, Information and Communication Engineers Technical Report, Japan, 2005.

Based on experience with GPS, and without requiring changes to the GPS receiver acceptance test requirements, there seems to be no risk in adding some clarification to the use of NAC_V by ATC automation systems indicating that considerably better than the high turn rate limiting encoded error value should be expected in the normal flight conditions which apply for the supported application. Normally experienced velocity errors at the 95th percentile should be on the order of one tenth of the encoded maximum value, for NAC_V equal to 1 or 2.

Appendix K

Velocity Accuracy As Affected By Report Assembly

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K Velocity Accuracy As Affected By Report Assembly

K.1 Purpose

This appendix provides documentation of analyses performed on velocity accuracy of the Mode S Extended Squitter. This analysis is intended to compare the velocity accuracy that results from the characteristics of the Extended Squitter against the velocity accuracy requirements given in the ADS-B MASPS.

K.2 Background

The 1090 MHz Extended Squitter ADS-B system transmits the surveillance state vector (position, velocity) information in two pieces. In order to form the full state vector some method of state vector reconstruction must be applied. This may involve filtering the incoming messages to time register a full state vector, reporting latent data in the state vector report, or a combination of both.

Two methods of state vector reconstruction are analyzed:

1. After receipt of a position message, update the position half of the state vector report but do not update velocity. After receipt of a velocity message, update both position (by extrapolation using the latest velocity data) and velocity (using the most recently received velocity message). (This is referred to as “minimum technique”.)

2. After receipt of either a position or velocity message, update both halves of the state vector report by applying a Kalman filter or other tracking filter. (This is referred to as “Kalman technique”.)

This Appendix analyzes the results using these two alternatives. The analysis is performed in two ways:

1. Use the ADS-B MASPS in a strict sense: Examine velocity errors after each state vector update.

2. Examine velocity errors once a second regardless of whether an ADS-B Message is received and an ADS-B State Vector Report is issued.

The analysis below applies to short-range surveillance, for which the nominal surveillance update period is 3 seconds. A related analysis is provided in Reference K-1, which applies to longer-range air-to-air surveillance, for which the nominal surveillance update time is 12 seconds. The results in Reference K-1 are consistent with the results given in this Appendix.

K.3 Scenarios and Results

To evaluate velocity accuracy, Monte-Carlo simulations of a maneuvering scenario were run. Statistical results on velocity accuracy were then collected using the scenario shown in Figure K-1. In this scenario, the aircraft travels at 150 knots, and executes 180 degree turn with a turn rate of 3 degrees per second. This results in an acceleration of slightly less than 0.5 g (where g is the acceleration due to gravity), the ADS-B MASPS defined limit condition for state vector accuracy.

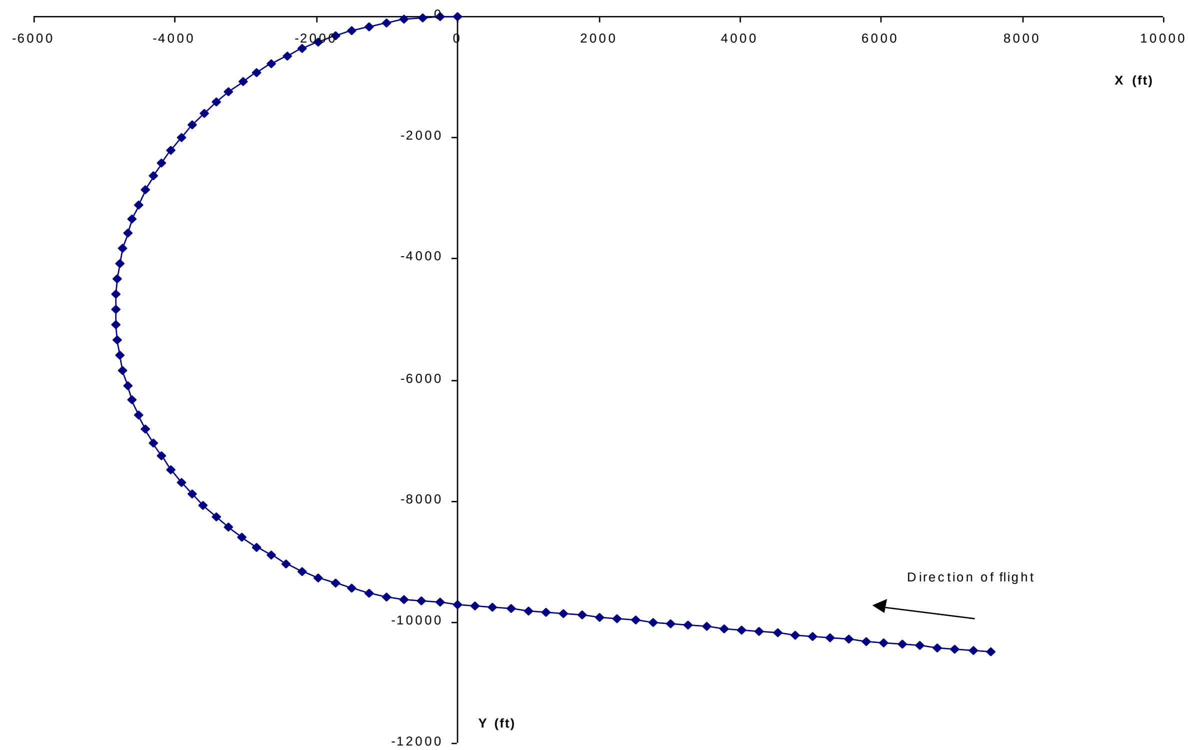

Figure K-1: Scenario Geometry Used in the Evaluation

Figure K-2 shows results for velocity errors after each state vector report update. In addition to the segmented message based results, results for a benchmark full state-vector message are included. Sending this hypothetical message at an update period of T=3 seconds, and a probability of receipt of 0.95 was simulated. These values correspond directly to the ADS-B MASPS requirements, from RTCA DO-242A, Table 3-4(a). The probability of Extended Squitter reception of 0.46 per message used in Figure K-2 was chosen because it is the minimum probability that assures reception of both a position message and a velocity message within a 3 second period with 0.95 probability.

It is observed that a benchmark full state vector update meets the ADS-B MASPS requirements as stated. This is because both position and velocity of the state vector report are updated with recent information upon receipt of a state vector message. The only errors introduced in velocity are quantization errors. The simulated quantization errors were chosen to meet the ADS-B MASPS requirements.

According to a literal interpretation of the ADS-B MASPS, the segmented state vector does not meet the ADS-B MASPS required accuracy for velocity after each state vector report update. However, the following analysis shows that state vector reports provided by the 1090 MHz Extended Squitter system have operational characteristics that conform to those implied by the ADS-B MASPS. The largest errors are observed when ADS-B receives position and velocity is not updated. Applying a Kalman filter to the segmented messages still does not result in compliance with the literal ADS-B MASPS requirements. With the segmented message set, the velocity portion of the state vector report lags the actual velocity after receipt of a position message. Without updating velocity after the receipt of a position message, the velocity is as old as the last velocity received. Applying a Kalman filter, velocity updates occur whenever a position report is received, but the resulting velocity estimates still lag the true velocity more than the MASPS allows.

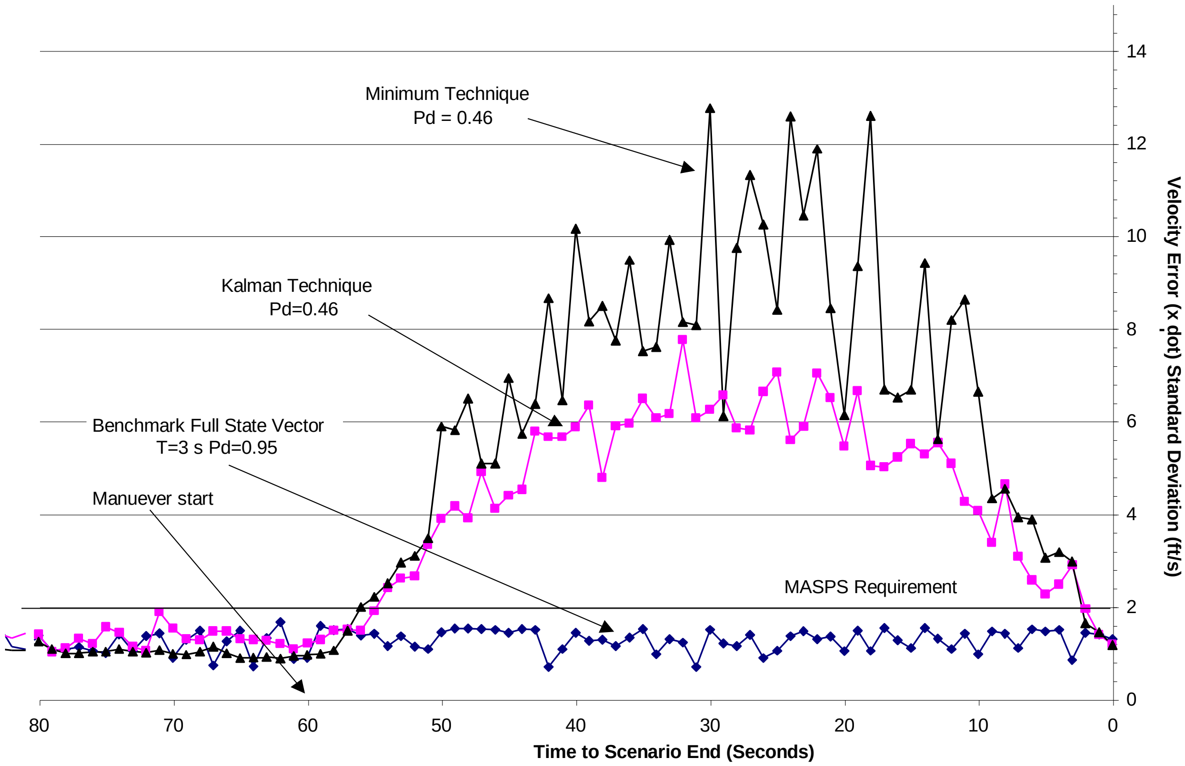

Figure K-2: Velocity Accuracy at Time of Each State Vector Report Update

Figure K-3 illustrates results of sampling the velocity error in 1 second epochs. In this case the velocity of a benchmark full state vector update with T=3 seconds will lag the true velocity for several seconds after each update. Since we do not expect ADS-B applications to synchronize their use of ADS-B data to the message transmission period, the error analysis shown in Figure K-3 may better represent the error observed by an ADS-B application than the error analysis shown in Figure K-2.

In a sense, the curve labeled “benchmark full state vector” in Figure K-3 represents the effective error observed by an application randomly sampling state vector reports that meet the letter of the ADS-B MASPS requirement. The benchmark full state vector curve can be thought of as the intent of the ADS-B MASPS, and ADS-B systems whose errors fall at or below this curve are meeting the operational intent of the ADS-B MASPS.

In this context, the squitter velocity accuracy needs reexamination. It is observed in Figure K-3 that the Extended Squitter state vector report accuracy is better than the benchmark full state vector curve for required (pd=0.46) detection probabilities, with or without a Kalman Filter. The benchmark is achieved with a Kalman filter and update probabilities as low as 0.26, and without a filter and update probabilities as low as 0.38.

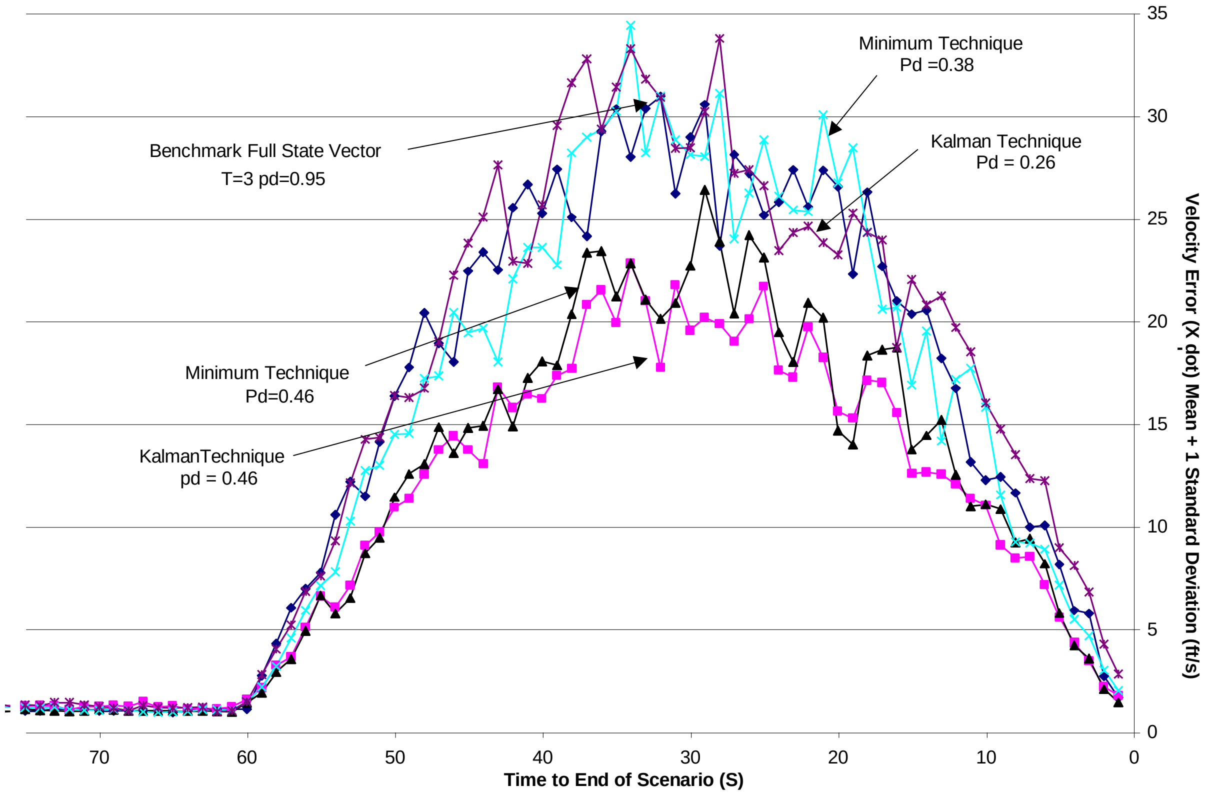

Figure K-3: Velocity Accuracy Sampled at 1 Second Epochs

K.4 A Minimum Report Assembly Technique

Following the requirements of §2.2.8.1, this section describes a minimum implementation of a state vector report assembly technique.

There are two methods of updating a state vector; one is used when a position report is received, and the other is used when a velocity measurement is received. For simplicity, only equations for the x coordinate of a state vector are shown here; an identical process was used for the y coordinate as well.

Upon receipt of the n^th position measurement a state vector is updated as follows:

$$\hat{x}(n) = x_m(n) \tag{4-1}$$

$$\hat{\dot{x}}(n) = \dot{x}_m(k) \tag{4-2}$$

where $x_m(n)$ is the n^th position measurement and $\dot{x}_m(k)$ is the most recently received velocity measurement, and $< \hat{x}(n), \hat{\dot{x}}(n) >$ is the x component of the state vector.

Upon receipt of the m^th velocity measurement the state vector is updated as follows:

$$\hat{x}(m) = \hat{x}(m-1) + dt(\dot{x}_m)(m) \tag{4-3}$$

$$\hat{\dot{x}}(m) = \dot{x}_m(m) \qquad (4\text{-}4)$$

where dt is the time difference between the last measurement and the current measurement.

K.5 A Kalman Filter Report Assembly Technique

The Kalman filter that was used in this analysis, and may be suitable for implementation for ADS-B, consists of three independent, two state Kalman filters. The filter's state consists of position and velocity. The state is tracked in each of three orthogonal Cartesian dimensions (x, y, and z). The state estimates are assumed to be independent in each of the three dimensions.

Linear dynamics are assumed in each of the three dimensions. The filter takes as input the measured position or velocity, the previous track state, and the previous track state covariance. The filter also requires as input the time of the measurement. The filter produces as output an updated track state and covariance.

The filter, which is identical in all three dimensions, will now be detailed.

K.5.1 Filter State and Covariance

The filter maintains a state consisting of position and velocity and a state covariance matrix that represents the uncertainty in the state estimate.

The filter state estimate in the x-dimension is represented by the vector: $\begin{pmatrix} \hat{x} & \hat{\dot{x}} \end{pmatrix}^t$. Note that here the variable "x" is used to show the filter state in one of the three dimensions; the y and z dimensions have a state and covariance representation which exactly parallels that of x. The covariance matrix of the state estimate in the x-dimension is represented by the matrix:

$$\begin{pmatrix} \sigma_{\hat{x}}^2 & \sigma_{\hat{x}\hat{\dot{x}}} \\ \sigma_{\hat{x}\hat{\dot{x}}} & \sigma_{\hat{\dot{x}}}^2 \end{pmatrix}$$

where

$\sigma_{\hat{x}}^2$ represents the variance in the position estimate;

$\sigma_{\hat{\dot{x}}}^2$ represents the variance in the velocity estimate;

$\sigma_{\hat{x}\hat{\dot{x}}}$ represents the covariance of position and velocity.

K.5.2 Initial State And Covariance

Before any measurements are received, the state estimates and the state covariance matrix are initialized. The state estimate is initialized by setting both the position and velocity estimate to zero. The state covariance matrix is initialized according to equation 5-1:

$$\begin{pmatrix} \sigma_{\hat{x}}^2 & \sigma_{\hat{x}\hat{\dot{x}}} \\ \sigma_{\hat{x}\hat{\dot{x}}} & \sigma_{\hat{\dot{x}}}^2 \end{pmatrix} = \begin{pmatrix} \infty & 0 \\ 0 & \infty \end{pmatrix} \qquad (5\text{-}1)$$

For the purposes of an actual implementation, infinity can be represented by a large real number.

K.5.3 Kalman Filter Steady State Algorithm

The standard Kalman filter consists of five steps:

1. State extrapolation
2. Covariance matrix extrapolation
3. Residual calculation
4. State vector update
5. Covariance matrix update.

The first two steps are identical regardless of whether the measurement is a position, velocity, or both. The last three steps depend on the form of the measurement.

K.5.3.1 State Extrapolation

The first step in the filter is to extrapolate the state estimates to the time of the current measurement. Equations 5-2 detail the mechanics of the state extrapolation:

$$\begin{aligned} \hat{\hat{x}} &= \hat{x} + \hat{\dot{x}}(dt) \\ \hat{\hat{\dot{x}}} &= \hat{\dot{x}} \end{aligned} \qquad (5\text{-}2)$$

where

$\hat{\hat{x}}$ is the predicted (extrapolated) x position;

$\hat{\hat{\dot{x}}}$ is the predicted velocity in the x direction;

$\hat{x}$ is the current position estimate for x;

$\hat{\dot{x}}$ is the current velocity estimate in the x direction;

dt is the time difference between the current measurement and the last state update.

K.5.3.2 Covariance Matrix Extrapolation

The next step in the filtering process is the extrapolation of the covariance matrix.

$$\sigma^2_{\hat{\hat{x}}} = \sigma^2_{\hat{x}} + (dt)^2\sigma^2_{\hat{\dot{x}}} + 2dt\,\sigma_{\hat{x}\hat{\dot{x}}} + \frac{Q(dt)^4}{4} \qquad (5\text{-}3)$$

$$\sigma^2_{\hat{\hat{\dot{x}}}} = \sigma^2_{\hat{\dot{x}}} + (dt)^2 Q \qquad (5\text{-}4)$$

$$\sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}} = \sigma_{\hat{\hat{\dot{x}}}\hat{\hat{x}}} = \sigma_{\hat{x}\hat{\dot{x}}} + (dt)\sigma^2_{\hat{\dot{x}}} + \frac{(dt)^3 Q}{2} \qquad (5\text{-}5)$$

where Q is the process (plant) noise variance.

Typical values are on the order of 0.0025 g^2. In our simulations, a second, higher value was used for Q when the ADS-B message indicated that a turning maneuver was taking place. The maneuver Q was set at 0.0625 g^2.

K.5.3.3 Track Residual, Filter Gain, Track Smoothing, and Covariance Update Calculations

The next three steps in the Kalman filter involve calculating the covariance of the measurement residual, calculating the filter gain, and updating the track state covariance estimate.

These calculations are dependent on the exact form of the measurement, and therefore differ depending on whether the received measurement is position or a velocity.

K.5.3.3.1 Residual Variance, Gain, Track Smoothing, and Covariance Update for Position Measurement

If the received measurement contains position information only, the filter gain is a two element vector and is calculated as shown below.

First, the residual (or innovations) variance is calculated:

$$\sigma_v^2 = \sigma_{\hat{\hat{x}}}^2 + \sigma_{x_m}^2 \qquad (5\text{-}6)$$

where

$\sigma_{x_m}^2$ is the variance of the position measurement.

The gain vector (**w**) is then calculated according to equations (5-7) and (5-8):

$$w_0 = \frac{\sigma_{\hat{\hat{x}}}^2}{\sigma_v^2} \qquad (5\text{-}7)$$

$$w_1 = \frac{\sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}}}{\sigma_v^2} \qquad (5\text{-}8)$$

The update of the state estimate is performed according to equations (5-9) and (5-10):

$$\hat{x} = \hat{\hat{x}} + w_0\left(x_m - \hat{\hat{x}}\right) \qquad (5\text{-}9)$$

$$\hat{\dot{x}} = \hat{\hat{\dot{x}}} + w_1\left(x_m - \hat{\hat{x}}\right) \qquad (5\text{-}10)$$

where

x_m is the current position measurement.

The update of the covariance matrix is then performed according to equations 5-11, 5-12, and 5-13:

$$\sigma_{\hat{\dot{x}}}^2 = (1 - w_0)\sigma_{\hat{\hat{x}}}^2 \qquad (5\text{-}11)$$

$$\sigma_{\hat{x}\hat{\dot{x}}} = (1 - w_0)\sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}} \qquad (5\text{-}12)$$

$$\sigma_{\hat{\dot{x}}}^2 = \sigma_{\hat{\hat{\dot{x}}}}^2 - w_1\sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}} \qquad (5\text{-}13)$$

The update of the state and covariance completes the Kalman filter operations for the current measurement.

K.5.3.3.2 Residual Variance, Gain, Track Smoothing, and Covariance Update for Velocity Measurement

In the case of a velocity measurement, the residual is the difference between the velocity prediction and the velocity measurement; the residual variance is then:

$$\sigma_v^2 = \sigma_{\hat{\hat{\dot{x}}}}^2 + \sigma_{\dot{x}_m}^2 \tag{5-14}$$

where

$\sigma_{\dot{x}_m}^2$ is the variance of the velocity measurement.

The filter gain vector is then calculated as shown below:

$$w_0 = \frac{\sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}}}{\sigma_v^2} \tag{5-15}$$

$$w_1 = \frac{\sigma_{\hat{\hat{\dot{x}}}}^2}{\sigma_v^2} \tag{5-16}$$

The track state is then updated through use of the velocity residual:

$$\hat{x} = \hat{\hat{x}} + w_0(\dot{x}_m - \hat{\hat{\dot{x}}}) \tag{5-17}$$

$$\hat{\dot{x}} = \hat{\hat{\dot{x}}} + w_1(\dot{x}_m - \hat{\hat{\dot{x}}}) \tag{5-18}$$

Finally, the track state covariance is updated as per equations 5-19 through 5-21:

$$\sigma_{\hat{x}}^2 = \sigma_{\hat{\hat{x}}}^2 - w_0 \sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}} \tag{5-19}$$

$$\sigma_{\hat{x}\hat{\dot{x}}} = (1 - w_1)\sigma_{\hat{\hat{x}}\hat{\hat{\dot{x}}}} \tag{5-20}$$

$$\sigma_{\hat{\dot{x}}}^2 = (1 - w_1)\sigma_{\hat{\hat{\dot{x}}}}^2 \tag{5-21}$$

K.6 Real Time Performance Evaluation

The Kalman filters described above were implemented in ANSI C, compiled using the Metrowerks "CodeWarrior" compiler with full optimization, and bench-marked on two Macintosh machines. The two machines were the Macintosh Power PC 7500 running at 100 MHz and a Macintosh Quadra running at 33 MHz. The Power PC uses the Motorola 601 processor; the Quadra uses a Motorola 68040 processing chip. Table K-1 shows the average run times for a position and velocity Kalman filter update measured on these machines using the CodeWarrior profiler. Run times on more recent processors should be appreciably smaller.

Table K-1: Run Time For Kalman Filter Update

Measurement Type	Power PC (100 MHz)	Quadra (33 MHz)
Position	2 μs	11 μs
Velocity	2 μs	11 μs

K.7 Conclusions

The 1090 MHz Extended Squitter ADS-B implementation, which segments state vectors into multiple messages, has been shown to meet the operational intent of the ADS-B MASPS velocity accuracy requirements associated with a 3 second 95% state vector update period without filtering in regimes where the probability of message reception after participant acquisition is greater than 0.38. To meet the ADS-B MASPS state vector update requirements for this scenario, the message reception probability must be 0.46 or higher. Therefore, velocity accuracy has been shown not to be the limiting factor for meeting the requirements for this scenario. Based on Figure K-3 results, acceptance tests for report assembly should recognize that user applications can still be supported with test results meeting the limits articulated in Figure K-2.

Appendix K - References

K-1. *1090 MHz Extended Squitter Assessment Report*, June 2002, prepared by the FAA and the Eurocontrol Experimental Centre. This report is available for download and review under the following RTCA SC-186 Working Group 3 web link for "Agendas, Minutes and Working Papers," in the table for Meeting 12, identified as Working Paper 1090-WP-12-05: http://adsb.tc.faa.gov/WG3.htm

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Appendix L

Impact of Radio Frequency Interference on Extended Squitter Report Integrity

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L Impact of Radio Frequency Interference on Extended Squitter Report Integrity

L.1 Undetected Report Error Rate

ADS-B system integrity is defined in the MASPS (RTCA DO-242A, §3.3.6.5) in terms of the probability of an undetected error in a report received by an application, given that the transmitting ADS-B system participant is supplied with correct source data. An important component of ADS-B integrity is attributable to radio interference, whose effects are largely controlled by the use of error detection and correction applied upon reception. Several different techniques for error detection and correction have been considered, including the techniques currently used in TCAS (defined in the TCAS MOPS, RTCA DO-185B) and several new techniques, described in Appendix I. The rate of undetected errors is a key consideration in the development of new techniques, because of the inherent trade between undetected error rate and reliable acceptance of signals. Analysis and simulation have been used by two organizations to evaluate performance in terms of undetected error rate in a number of cases. Results of these evaluations, carried out for the LAX-99 interference environment, are summarized in Table L-1 and shown in more detail in Figure L-1. From the results in the table, it has been concluded that the undetected error rate increases as receiver MTL is reduced, and that the conservative error correction technique and the enhanced error correction technique are effective in controlling the error rate. As a result, these MOPS standards now require conservative error correction or enhanced error correction for all equipment Classes other than A0. Note, therefore, that some of the rows in Table L-1 are hypothetical combinations that are not allowed by these MOPS.

Table L-1: Undetected Report Error Rate

Receiver MTL (referred to antenna)	Reception and Error Correction Techniques	Evaluated contribution to undetected error rate (per report)	
		William J. Hughes Technical Center, FAA	MIT Lincoln Laboratory
MTL ≤ -72 dBm	DO-260 reception techniques DO-260 error correction	0.09 x (10^{-6})	0.08 x (10^{-6})
MTL ≤ -74 dBm	DO-260 reception techniques DO-260 error correction	0.15 x (10^{-6})	1.4 x (10^{-6})
MTL ≤ -79 dBm	DO-260 reception techniques DO-260 error correction	1.4 x (10^{-6})	3.9 x (10^{-6})
	DO-260 reception techniques DO-260 error correction	5 x (10^{-6})	10.1 x (10^{-6})
MTL ≤ -84 dBm	DO-260 reception techniques Conservative error correction	N/A	< 0.01 x (10^{-6})
	Enhanced reception techniques Enhanced error correction	N/A	0.05 x (10^{-6})

The last row of Table L-1 applies directly to Class A3 equipment, and the first row applies to Class A0. Because of the higher MTL values in Classes A2, A1 and A1S, relative to A3, lower error rates are expected, but because of the statistical nature of the Monte Carlo technique, it was not practical to evaluate these cases directly. The summary that follows provides error rate bounds for these two classes.

Class A3, error rate is approximately 0.05 x (10^{-6}) per report

Class A2, error rate < 0.05 x (10^{-6}) per report

Class A1S, error rate < 0.05 x (10^{-6}) per report

Class A1, error rate < 0.05 x (10^{-6}) per report

Class A0, error rate is approximately 0.09 x (10^{-6}) per report.

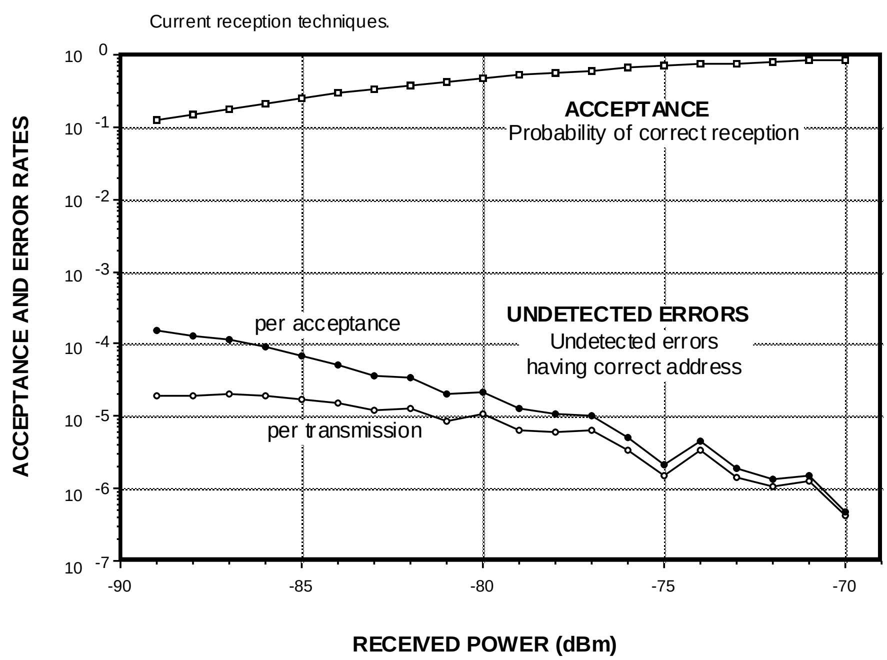

Figure L-1: Simulation Results Giving Acceptance Probability and Undetected Error Rate.

Based on the results in Table L-1, that show that lower MTL is associated with higher error rates, a more detailed study was undertaken, producing the results in Figure L-1. Reception rates are shown here as a function of received power level, giving both acceptance of valid signals (the upper curve) and undetected errors (the lower curves). A Monte Carlo simulation was used to obtain these results. The data in Figure L-1 is limited to the RTCA DO-260 reception techniques, which do not have the benefit of conservative or enhanced error correction. Otherwise, the error rates are much lower, and it is more difficult to assess performance using the Monte Carlo technique.

More specifically, the upper curve in Figure L-1 shows the probability of correct signal acceptance, including the effects of error detection and correction, as a function of received signal power. The lower curves represent the probability that an undetected error is received and is reflected in an ADS-B report. Simulation results are shown here in two forms, normalized to the transmission rate in the lower curve, and normalized to the reception rate in the middle curve.

The results show a clear trend in which the error rate, expressed either way, degrades as received signal power decreases. This behavior is consistent with the results in Table L-1. Together they underscore the need for the additional performance requirement when receiver MTL is enhanced relative to TCAS receivers.

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Appendix M

Extended Range Reception Techniques

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M Extended Range Reception Techniques

M.1 Purpose and Scope

The purpose of this Appendix is to provide a description of techniques for extending the effective air-to-air reception range of 1090 MHz ADS-B systems. Two reception techniques are explored: (1) use of a directional antenna with an integral low noise preamplifier for 1090 MHz Extended Squitter reception; (2) optimized 1090 MHz ADS-B reception employing a reduced bandwidth receiver to provide improved reception sensitivity under low-to-moderate 1090 MHz fruit conditions. Also the transmission power for Class A3 airborne installations is discussed.

M.2 Background

The ADS-B MASPS, RTCA DO-242A, specifies the required air-to-air reception range for a number of ADS-B applications. The one application identified by RTCA DO-242A with the longest reception range requirement is the Long Range Conflict Management application. When the requirements of all applications defined by RTCA DO-242A are considered, the required reception range varies as a function of target bearing from the receiving aircraft. Specifically as defined in RTCA DO-242A, Note 3 to Table 3-4(a), the required air-to-air reception range that would be applicable to Class A3 ADS-B systems is:

- 90 NM required (120 NM desired) in the forward direction
- 64 NM required (85 NM desired) +/- 45 degrees of forward direction
- 45 NM required toward the port and starboard directions
- 40 NM required (42 NM desired) toward the aft

RTCA DO-242A defines the Long Range Conflict Management (i.e., flight path de-confliction) application as being applicable to "cooperative separation in oceanic/low density en route airspace." Thus as currently defined by the ADS-B MASPS, this application is not explicitly required to be supported in moderate to high traffic density en route or terminal airspace. Currently the most demanding applications applicable to high density, high interference airspace are associated with separation assurance and sequencing. RTCA DO-242A only requires air-to-air reception ranges of 40 NM to support such applications. However, RTCA DO-242A includes similar notes under Tables 2-8 and 3-4(a) stating that "…the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas." The latter statement in this note applies by reference to the Long Range Conflict Management application.

Additional optimizations in the design of airborne 1090 MHz ADS-B systems may prove useful in satisfying the air-to-air reception range requirements associated of future ADS-B applications.

M.3 Current Reception Range

The most capable class of ADS-B receiver specified by these MOPS is for Class A3. This receiver class is specified to have an MTL of –84 dBm. An A3 class receiver when used in conjunction with omni-directional diversity aircraft antennas is intended to satisfy the requirement of RTCA DO-242A for an air-to-air reception range of 90 NM. This assumes all of the target aircraft of interest at the maximum range are equipped with Transmitter Class A3 having a transmit power (at the antenna) of 125 watts to 500 watts (see M.5 below). The 90 NM reception range capability is thus focused on users operating in high altitude airspace where the most capable class of avionics would be applicable. Also the Class A3 requirements included in these MOPS that are associated with a 90 NM reception range were predicated on a low-density airspace with low levels of RF interference.

M.4 Techniques for Extended Reception Range

The focus of this Appendix is on detailing techniques to provide for extended reception range (i.e., beyond 90 NM) in the forward direction, especially in low to moderate 1090 MHz fruit environments. Certain of these techniques apply only to receivers and antennas not shared with TCAS or used for by Mode S transponders for transmissions. This is a consequence of employing antennas and receiver characteristics that are optimized specifically for the reception of 1090 MHz Extended Squitters in support of the ADS-B function. The described techniques for enhanced reception range apply primarily to Class A3 receivers. Further, these techniques apply specifically to extending the ADS-B reception range between aircraft operating in high altitude en route or oceanic airspace. Some of the described techniques are expected to also prove useful in supporting increased air-to-air reception range while over-flying high density, high interference operational environments.

The approach described would add a dedicated directional receive-only antenna to the top of the airframe in combination with a 1090 MHz receiver optimized for extended squitter reception.

M.4.1 Optimized 1090 MHz Antenna

The proposed approach for supporting an extended squitter reception range would include the provision of an additional dedicated aircraft 1090 MHz receive-only antenna (i.e., a third antenna in addition to the baseline diversity antennas) with a gain pattern that is optimized for the required ADS-B system performance requirements, as summarized in section M.2 above. The baseline aircraft antenna configuration that is applicable to Class A3 ADS-B airborne systems is assumed to employ omni-directional top and bottom diversity antennas and are assumed to be consistent with the characteristics described in Appendix C. A more optimum aircraft antenna configuration is possible where a third antenna is added that is optimized specifically for the reception of 1090 MHz Extended Squitters at the maximum range in the forward direction. Such an optimized aircraft antenna configuration employing 3 antennas must still support reception at the ranges required by RTCA DO-242A in non-forward directions and must, at least, not degrade reception performance in the highest 1090 MHz fruit environments. A candidate optimized aircraft antenna configuration is described below that satisfies these constraints.

In this optimized configuration the diversity top and bottom aircraft antenna have antenna gain pattern characteristics as in a baseline 1090 MHz ADS-B configuration (i.e., omni-directional). However, for extended reception range these standard diversity antennas are supplemented with a top-mounted multi-element directional antenna providing a nominal +2 to +5 dB of additional gain in the forward direction, as compared to an omni-directional antenna. A typical configuration for the enhanced directional aircraft antenna is summarized below:

- employs one driven quarter wavelength element and one or more passive elements. The elements are tuned to provide peak gain and minimum VSWR at or near 1090 MHz. and providing a nominal +2 to +5 dB gain increase at or just above the horizon in the forward direction (exclusive of any internal amplification), as compared to the baseline omni-directional antenna.

- includes an internal low noise preamplifier with 12 dB to 15dB of gain and a noise figure at 1090 MHz. consistent with the overall MTL requirements of the receiving system.

The directional top antenna is to be used in combination with omni-directional top and bottom diversity antennas and each of the three antennas would be connected to independent 1090 MHz receivers. Since the directional top antenna would be dedicated to ADS-B reception, this could allow for a more optimum mounting location to be selected in support of the goal of providing improved reception performance from the forward direction. This would typically lead to a desired mounting location forward on the airframe's top center-line.

M.4.2 Optimized Receiver Characteristics

M.4.2.1 Optimized Receiver Bandwidth

Class A3 receivers that are not shared with TCAS are specified to have an MTL (at the antenna) of –84 dBm (Table 2-62 of these MOPS). The out-of-band rejection for a message frequency difference of ± 5.5 MHz is specified by Table 2-63 of these MOPS to be at least 3 dB above this MTL. These out-of-band rejection characteristics correspond to a receiver design that employs intermediate frequency (IF) filtering with an effective bandwidth of approximately 8 MHz. Modeling of the enhanced decoding techniques, as defined in Appendix I of these MOPS, have shown that reducing the IF bandwidth to significantly less than 8 MHz (e.g., 4 MHz) may slightly degrade the enhanced decoder performance in very high 1090 MHz Mode A/C fruit environments. However, such a reduction in the IF bandwidth will allow for decreased receiver MTL values resulting in improved reception range when used in low-to-moderate Mode A/C fruit environments. An optimum 1090 MHz Extended Squitter airborne architecture would allow for use of a narrower bandwidth receiver connected to a dedicated top-mounted directional antenna, as described in section M.4.1 above.

The use of a dedicated ADS-B receiver with reduced bandwidth provides the opportunity for improving the sensitivity of the receiver. The MTL for Class A3 receivers, conformant to these MOPS, is –84 dBm or lower (Table 2-62). Airborne installations may achieve up to a 3 dB improvement from this reception performance level (i.e., MTL less than or equal to -87 dBm) as a direct result of the reduction of the receiver bandwidth, as described above.

Additional improvements in receiver sensitivity are possible with the use of a low noise preamplifier mounted near or integral with the dedicated receiving antenna as described in section M.4.1 above. If an antenna-mounted low noise preamp is used in combination with a narrow bandwidth receiver, then a receiver MTL as low as –90 dBm may be possible. Such a configuration could be used to provide for maximum reception range in a low to moderate 1090 MHz. fruit environment.

M.4.2.2 Optimized Receiver Extended Squitter Decoding

Class A3 receivers are required by these MOPS to incorporate enhanced reception techniques. The associated test procedures of these MOPS are consistent with an 8 MHz sampling rate of the received video waveform (i.e., 8 samples per bit). Higher sampling rates are known to provide improved probability of correct decoding when using the baseline multi-sample enhanced decoding techniques defined in Appendix I in a high Mode A/C fruit environment. Therefore, a sampling rate of 10 MHz or higher is recommended for use as a means of extending the reception range of 1090 MHz ADS-B in high Mode A/C fruit environments. Applying a decoder with a higher sampling rate is expected to help offset the degradation to decoding performance that would result from use of a reduced bandwidth receiver as described in M.4.2.1 above.

M.5 Transmission Power

Currently all 1090 MHz ADS-B airborne systems, other than Class A0, are required by these MOPS to have a transmit power within the range of 21 dBW (125 watts) to 27 dBW (500 watts), as measured at the antenna port. As noted in §2.2.2.1.1.4 of these MOPS: "Future version of these MOPS may require that Class A3 1090 MHz ADS-B systems have a transmission capability with a minimum RF peak power of 23 dBW (200 Watts) measured at the antenna terminals." As the ADS-B MASPS mature, further refinements to the air-to-air range requirements are expected. Also as the ASA MASPS are completed new requirements may emerge that require either improvements in received update rates or increased reception ranges. A 1090 MHz ADS-B airborne installation satisfying only the minimum transmit power requirement of 21 dBW, as currently required by these MOPS, is expected to be compatible with the 90 NM reception range requirement, as applicable to Class A3 systems, only under near ideal conditions (with a nominal antenna gain patterns and in a RF non-interference environment). A 2dB increase in the minimum transmit power from 21 dBW to 23 dBW for Class A3 airborne systems is expected to offer a meaningful improvement in the actual air-to-air reception range supported between Class A3 users, especially under non-ideal conditions.

Appendix N

Proposed DO-260B Provisions for Backward Compatibility with DO-260 and DO-260A

Message Formats

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N Proposed DO-260A Provisions for Backward Compatibility with DO-260 Message Formats

N.1 Introduction

N.1.1 Purpose of this Appendix

This Appendix:

a) Defines the formats and coding for extended squitter ADS-B Messages that are broadcast by ADS-B Version Zero (0), RTCA DO-260 conformant 1090 MHz ADS-B Subsystems; and

b) Defines how the ADS-B report generation function of Version One (1) 1090 MHz ADS-B Receiving Subsystems is to utilize messages received from targets that are broadcasting with Version Zero (0) message formats.

N.1.2 Message Version Number

The Version Number for all 1090 MHz ADS-B Messages originating for each specific ADS-B target is determined from the decoding of the Version Number subfield of the Aircraft Operational Status Message. An ADS-B Version One (1) Receiving Subsystem initially assumes that the messages conform to Version Zero (0) message formats, until or unless received Version Number data indicates otherwise. The Version Number is retained and associated with all messages from that specific target. This Version Number is used for determining the applicable message formats to be applied for the decoding of all 1090 MHz ADS-B Messages received from that target.

N.2 1090 MHz ADS-B Message Types

Table N-1 provides those ADS-B Version Zero (0) (i.e., originating from a RTCA DO-260 conformant 1090 MHz ADS-B Transmitting Subsystem) 1090 MHz ADS-B Messages that are to be used for ADS-B report generation by a Version One (1) conformant 1090 MHz ADS-B Receiving Subsystem.

Note: *Table N-1 lists only those Version Zero (0) 1090 MHz ADS-B Message types that are required to be received and used for ADS-B report generation by a Version One (1) 1090 MHz ADS-B Receiving Subsystem. The other Version Zero (0) ADS-B Messages types defined by RTCA DO-260, including messages types 29 and 30, are not to be used by Version One (1) ADS-B Receiving Subsystems for the purpose of ADS-B report generation.*

Table N-1: Version Zero (0) ADS-B Message Types

Message Format TYPE Code(s)	Assignment	Nominal Broadcast Rate
1 through 4	Extended Squitter Identification and Category	5.0 s airborne/10.0 s surface
5 through 8	Extended Squitter Surface Position	0.5 s in motion/5.0 s stationary
9 through 18 and 20 through 22	Extended Squitter Airborne Position	0.5 s
19	Extended Squitter Airborne Velocity	0.5 s
28	Extended Squitter Aircraft Status (e.g., emergency/priority)	1.0 s
31	Aircraft Operational Status	1.7 s

N.2.1 Message TYPE Codes

The first 5-bit field in every 1090 MHz ADS-B Message contains the message format TYPE. As shown in Table N-2, the TYPE code (i.e., format type) is used to differentiate the messages into several classes: airborne position, airborne velocity, surface position, identification, aircraft status, etc. The general definition for all ADS-B Messages Types used for Version Zero (0) ADS-B Messages has been retained for Version One (1) messages. It must be noted for Version Zero (0) ADS-B Messages, format TYPE Code 29 was defined but the corresponding messages were not to be transmitted. For Version Zero (0) ADS-B Subsystems, TYPE code 29 was associated with intent messages conveying Trajectory Change Point (TCP) information. Although the message formats for TCP related messages were defined within RTCA DO-260 the requirements and the associated test procedures prohibited the broadcast of such messages. RTCA DO-260 defined TYPE Code 30 for Aircraft Operational Coordination Messages. The requirements and associated provisions for Aircraft Operational Coordination Messages have now been withdrawn by this version of these MOPS. Although RTCA DO-260 (i.e., Version 0) conformant implementations are not prohibited from transmitting Aircraft Operational Coordination Messages (i.e., using TYPE Code 30), Version One (1) conformant ADS-B Receiving Subsystems have no requirement for the reception and processing of these broadcasts. Version One (1) ADS-B Receiving Subsystems will generate ADS-B reports based only on the reception of Version Zero (0) ADS-B Messages with ADS-B Message TYPE Code values of 0 through 22, 29 and 31.

Table N-2: Format TYPE Codes for Version 0 and Version 1 Messages

TYPE Code	Version 0 Message Format	Version 1 Message Format
0	No Position Information	No Position Information
1	Identification (Category Set D)	Identification (Category Set D)
2	Identification (Category Set C)	Identification (Category Set C)
3	Identification (Category Set B)	Identification (Category Set B)
4	Identification (Category Set A)	Identification (Category Set A)
5	Surface Position	Surface Position
6	Surface Position	Surface Position
7	Surface Position	Surface Position
8	Surface Position	Surface Position
9	Airborne Position	Airborne Position
10	Airborne Position	Airborne Position
11	Airborne Position	Airborne Position
12	Airborne Position	Airborne Position
13	Airborne Position	Airborne Position
14	Airborne Position	Airborne Position
15	Airborne Position	Airborne Position
16	Airborne Position	Airborne Position
17	Airborne Position	Airborne Position
18	Airborne Position	Airborne Position
19	Airborne Velocity	Airborne Velocity
20	Airborne Position	Airborne Position
21	Airborne Position	Airborne Position
22	Airborne Position	Airborne Position
23	Reserved for Test Purposes	Test Message
24	Reserved for Surface System Status	Reserved for Surface System Status
25	Reserved	Reserved
26	Reserved	Reserved
27	Reserved	Reserved for Trajectory Change
28	Extended Squitter Aircraft Status	Extended Squitter Aircraft Status
29	Reserved for Trajectory Intent	Target State and Status
30	Operational Coordination	Reserved
31	Operational Status	Operational Status

N.3 State Vector Reports Generated using Version Zero (0) Messages

The following subparagraphs summarize the ADS-B State Vector Report generation requirements (see §2.2.8.1) for Version One (1) systems when receiving Version Zero (0) ADS-B Messages.

The contents of State Vector Reports are specified in Table 2.2.8.1. The contents of the State Vector Reports are composed primarily from the information received from airborne aircraft in Airborne Position Messages and Airborne Velocity Messages or for aircraft/vehicles on the airport surface in Surface Position Messages. Many of the parameters contained within these messages are encoded the same, and occupy the same positions with the overall message structure, for both Version Zero (0) and for Version One (1) messages. However, in a few cases the decoding and/or report assembly processing must be handled differently for Version Zero (0) messages as compared to that required by these MOPS (§2.2.8.1) for Version One (1) messages. The following subparagraphs describe the required use of Version Zero (0) messages for ADS-B report generation by a Version One (1) compliant ADS-B Receiving Subsystem.

N.3.1 State Vector Report to 1090 MHz ADS-B Message Mapping

Table 2.2.8.1 specifies the overall State Vector Report format and the source for each parameter that is to be reported when the target aircraft/vehicle is broadcasting with Version One (1) ADS-B Message formats. In a similar fashion, Table N-3 below defines the 1090 MHz ADS-B Message-to-State Vector Report mapping that will be used when the target aircraft/vehicle is broadcasting using Version Zero (0) ADS-B Messages. Note there are some minor differences in the specific names applied to certain otherwise identical Version Zero (0) versus Version (1) messages subfields. The only new or changed State Vector Report parameter between RTCA DO-260 (i.e., Version 0) and these MOPS is for Navigation Integrity Category (NIC), which has replaced Navigation Uncertainty Category (NUC) from the initial version of these MOPS. The following subparagraph discusses the NIC parameter and its mapping from Version Zero (0) messages to the State Vector Report. The remaining State Vector Report parameters are described in §2.2.8.1.

The format of the Version Zero (0) 1090 MHz ADS-B Messages are specified in Figure N-1 through Figure N-7.

Table N-3: ADS-B State Vector Data Elements – Version Zero (0) 1090 MHz ADS-B Messages to Report Structure Mapping

Column #	REPORT STRUCTURE		VERSION ZERO (0) MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	**Parameter / Contents**	**Notes**	**Received Message Structure**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
0a, 0b	Report Type and Structure Identification	4	Airborne Position - "DF"	N/A	1 – 5	24	N/A	N/A	discrete	MddL Mddd dddddddd ddddddL	0 -2
0c	Validity Flags		N/A	N/A	N/A	16	N/A	N/A	discrete	dddddddd dddddddd	3 - 4
1	Participant Address	4	Airborne Position - "AA" Surface Position - "AA" Airborne Velocity – "AA"	N/A N/A N/A	9 - 32 9 – 32 9 - 32	24	N/A	N/A	discrete	Mddddddd dddddddd DddddddL	5 - 7
2	Address Qualifier		N/A	N/A	N/A	8	N/A	N/A	discrete	00000M0L	8
3	Time of Applicability (Position and Velocity)	4	Airborne Position – "Time" Surface Position – "Time" Airborne Velocity	21 21 N/A	53 53 N/A	24	511.9921875	0.0078125 (1/128)	seconds	Mddddddd ddddddL Mddddddd ddddddL Mddddddd ddddddL	9 - 11
4	Latitude (WGS-84)	4	Airborne Position – "Encoded Latitude" Surface Position – "Encoded Latitude"	23 - 39 23 - 39	55 - 71 55 – 71	24	+/- 180	0.0000215	degrees	SMdddddd dddddddd DddddddL	12 - 14
5	Longitude (WGS-84)	4	Airborne Position – "Encoded Longitude" Surface Position – "Encoded Longitude"	40 - 56 40 - 56	72 - 88 72 – 88	24	+/- 180	0.0000215	degrees	SMdddddd dddddddd DddddddL	15 - 17
6	Altitude, Geometric (WGS-84)	4, 5	Airborne Position – "TYPE", **&** "Altitude" Airborne Velocity – "Diff. Sign Bit" & "Geo Height Diff. from Baro. Alt."	1 - 5, **&** 9 - 20 49 50 - 56	33 - 37 41 – 52 81 82 - 88	24	+/- 131,072	0.015625	feet	SMdddddd dddddddd dddddddL	18 - 20
7	North / South Velocity	4, 5	Airborne Velocity – "Direction Bit for N-S Vel." & "N/S Velocity"	25 26 - 35	57 58 – 67	16	+/- 4,096	0.125	knots	SMdddddd dddddddL	21 - 22
8	East / West Velocity	4, 5	Airborne Velocity – "Direction Bit E-W Vel." & "E/W Velocity"	14 15 - 24	46 47 – 56	16	+/- 4,096	0.125	knots	SMdddddd dddddddL	23 - 24
9	Ground Speed while on the Surface	4, 6	Surface Position – "Movement"	6 - 12	38 – 44	8	N/A	N/A	discrete	MddddddL	25

Column #	REPORT STRUCTURE		VERSION ZERO (0) MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	**Parameter / Contents**	**Notes**	**Received Message Structure**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
10	Heading while on the Surface	4, 6	Surface Position – "Ground Track"	14 - 20	46 – 52	8	+/- 180	1.40625	degrees	SMddddddL	26
11	Altitude, Barometric (Pressure Altitude)	4, 5	Airborne Position – "TYPE", & "Altitude"	1 - 5 9 - 20	33 – 37 41 – 52	24	+/- 131,072	0.015625	feet	SMddddddd dddddddd ddddddddL	27 - 29
12	Vertical Rate, Geometric/Barometric (WGS-84)	4, 5	Airborne Velocity – "Source Bit for Vert. Rate ", "Sign Bit for Vert. Rate " & "Vert. Rate"	36 37 38 - 46	68 69 70 – 78	16	+/- 32,768	1.0	ft./min.	SMddddddd ddddddddL	30 - 31
13	Navigation Integrity Category (NIC)	4	Airborne Position "Type Code" Surface Position "Type Code"	1 – 5 1 - 5	33 – 37 33 - 37	8	N/A	N/A	discrete	0000MddL	32
14	Estimated Latitude (WGS-84)	7	Airborne Position – "Encoded Latitude" Surface Position – "Encoded Latitude"	23 - 39 23 - 39	55 - 71 55 – 71	24	24	+/- 180	0.0000215	degrees	33 - 35
15	Estimated Longitude (WGS-84)	7	Airborne Position – "Encoded Longitude" Surface Position – "Encoded Longitude"	40 - 56 40 - 56	72 - 88 72 – 88	24	24	+/- 180	0.0000215	degrees	36 - 38
16	Estimated North/South Velocity	7	Airborne Velocity – "Direction Bit for N-S Vel." & "N-S Velocity"	25 26 - 35	57 58 – 67	16	+/- 4,096	0.125	knots	SMddddddd ddddddddL	39 - 40
17	Estimated East/West Velocity	7	Airborne Velocity – "Direction Bit for E-W Vel." & "E-W Velocity"	14 15 - 24	46 47 – 56	16	+/- 4,096	0.125	knots	SMddddddd ddddddddL	41 - 42
18	Surveillance Status/Discretes		Airborne Position – "Surveillance. Status" Airborne Velocity – "Intent Change Flag"	6 – 7 9	38 – 39 9	4 4	N/A	N/A	discrete	dddd dddd	43
19	Report Mode		N/A	N/A	N/A	8	N/A	N/A	discrete	000000ML	44
										TOTAL BYTES	45

Notes for Table N-3:

1. *In the "Data Structure" column (i.e., column 10), "S" indicates the "sign-bit," "M" indicates the Most Significant Bit of the data field, "d" indicates data bits in the field, "L" indicates the Least Significant Bit of the data field, "0" indicates the bit is to always be set to a value of zero (0) and "x" indicates "Don't Care" bits in the data field.*

2. *If data is not available to support theses fields, then the entire data field shall be set to ALL ZEROs if the field is delivered to the application.*

3. *The Report Type Identifier is used to identify the type of ADS-B Report being generated as defined in §2.2.8.1.1.1.*

4. *Items annotated with Note 4 represent "Critical" State Vector items, however certain items are only applicable while airborne and others only applicable while on the surface (see Notes 5 and 6 below).*

5. *Parameters annotated with Note 5 are only present in the State Vector Report when the aircraft is airborne*

6. *Parameters annotated with Note 6 are only present in the State Vector Report with the aircraft is on the airport surface*

7. *Estimated values may be either an actual value from a received message, if available, or a calculated value such as produced by a surveillance tracker algorithm. For example it is possible for a surveillance tracker to produce an updated estimate of the target's horizontal position based on just the receipt of a new velocity message.*

8. *The Time of Applicability is actually a grouping of 3 individual parameters as defined in §2.2.8.1.4*

N.3.1.1 Navigation Integrity Category (NIC)

The ADS-B Version Zero (0) Surface and Airborne Position Messages have associated with each specific TYPE Code a corresponding Horizontal Protection Limit and a 95% Containment Radius. For the purpose of generating a State Vector Report, RTCA DO-260 (i.e., Version 0) mapped these message parameters to a Navigation Uncertainty Category (NUC). As defined by Table 2-11, Version One (1) Surface and Airborne Position Messages associated the ADS-B Message TYPE Code with the parameters of Horizontal Containment Limit (R_C) and Navigation Integrity Category (NIC). Although Version Zero (0) ADS-B Messages were not defined by RTCA DO-260 to directly include a value for NIC, the values defined by Table 2-11 for R_C and NIC have been selected such that the it is possible to map the TYPE Code values from Version Zero (0) ADS-B Message to a corresponding value for NIC. The Surface and Airborne Position Message TYPE Codes associated with Version Zero (0) 1090 MHz ADS-B Messages are mapped to the NIC values shown in Table N-4 for the purpose of generating State Vector Reports.

Table N-4: Version Zero (0) Format Type Code Mapping to Navigation Source Characteristics

“TYPE” Subfield Code Definitions (DF = 17 or 18)				
TYPE **Code**	**Format**	**Horizontal Protection Limit, HPL**	**Altitude Type**	**Reported NIC**
0	No Position Information		Baro Altitude or No Altitude Information	0
5	Surface Position	HPL < 7.5 m	No Altitude Information	11
6	Surface Position	HPL < 25 m	No Altitude Information	10
7	Surface Position	HPL < 185.2 m (0.1 NM)	No Altitude Information	8
8	Surface Position	HPL ≥ 185.2 m (0.1 NM)	No Altitude Information	0
9	Airborne Position	HPL < 7.5 m	Baro Altitude	11
10	Airborne Position	7.5 m ≤ HPL < 25 m	Baro Altitude	10
11	Airborne Position	25 m ≤ HPL < 185.2 m (0.1 NM)	Baro Altitude	8
12	Airborne Position	185.2 m (0.1 NM) ≤ HPL < 370.4 m (0.2 NM)	Baro Altitude	7
13	Airborne Position	380.4 m (0.2 NM) ≤ HPL < 926 m (0.5 NM)	Baro Altitude	6
14	Airborne Position	26 m (0.5 NM) ≤ HPL < 1852 m (1.0 NM)	Baro Altitude	5
15	Airborne Position	1852 m (1.0 NM) ≤ HPL < 3704 m (2.0 NM)	Baro Altitude	4
16	Airborne Position	7.704 km (2.0 NM) ≤ HPL < 18.52 km (10 NM)	Baro Altitude	1
17	Airborne Position	18.52 km (10 NM) ≤ HPL < 37.04 km (20 NM)	Baro Altitude	1
18	Airborne Position	HPL ≥ 37.04 km (20 NM)	Baro Altitude	0
20	Airborne Position	HPL < 7.5 m	GNSS Height (HAE)	11
21	Airborne Position	HPL < 25 m	GNSS Height (HAE)	10
22	Airborne Position	HPL ≥ 25 m	GNSS Height (HAE)	0

Notes for Table N-4:

1. *“Baro-Altitude” refers to barometric pressure altitude, relative to a standard pressure of 1013.25 millibars (29.92 in Hg). It does not refer to baro corrected altitude.*

2. *The GNSS height (HAE) defined in Type Codes 20 to 22 is used when baro altitude is not available.*

3. *The horizontal protection level, HPL, is derived from ARINC 429 label 130, which is variously called HIL (Horizontal Integrity Limit) or HPL (Horizontal Protection Level).*

N.4 Mode Status Reports

Table 2.2.8.2 defines the overall Mode Status Report format and the source for each parameter that is to be reported when the target aircraft/vehicle is broadcasting with Version One (1) ADS-B Message formats. In a similar fashion, Table N-5 below defines the 1090 MHz ADS-B Message-to-State Vector Report mapping that will be used when the target aircraft/vehicle is broadcasting using Version Zero (0) ADS-B Messages. Note that there are some significant differences in the message parameters available from Version Zero (0) versus Version (1) ADS-B Messages. This results in Mode Status Reports related to target aircraft/vehicles broadcasting Version Zero (0) ADS-B Messages being substantially less complete than would be possible when Version One (1) ADS-B Messages are being received. The following subparagraphs discuss those Mode Status Report parameters that must be processed and/or mapped differently for Version Zero (0) ADS-B Messages. The remaining Mode Status Report parameters not specifically addressed in the following subparagraphs will be generated as specified in §2.2.8.2 (i.e., using the same mapping as for Version One (1) ADS-B Messages).

The format of the Version Zero (0) 1090 MHz ADS-B Messages are specified in Figure N-1 through Figure N-7.

Table N-5: ADS-B Mode Status Data Elements – Version Zero (0) 1090 MHz ADS-B Messages to Report Structure Mapping

Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	**Parameter / Contents**	**Notes**	**Received Version 0 Message Sources**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
0a,0b	Report Type and Structure		N/A	N/A	N/A	24	N/A	N/A	discrete	MddL Mddd dddddddd dddddddL	0 - 2
0c	Validity Flags		N/A	N/A	N/A	8	N/A	N/A	discrete	dddddddd	3
1	Participant Address		Airborne Velocity - "AA" - OR - Operational Status – "AA" - OR - Aircraft Identification – "AA"	N/A N/A N/A	9 – 32 9 – 32 9 – 32	24 24 24	N/A	N/A	discrete	Mddddddd dddddddd dddddddL	4 – 6
2	Address Qualifier		N/A reserved for future use			8	N/A	N/A	discrete	00000M0L	7
3	Time of Applicability		N/A	N/A	N/A	16	511.9921875	0.0078125 (1/128)	seconds	Mddddddd dddddddL	8 - 9
4	ADS-B Version		Operational Status – "Version Number"	41 - 43	73 - 75	8	0 - 7	1	discrete	00000MdL	10
5a	Call Sign		Aircraft Identification – "Ident Char."	14 – 56	41 – 88	64	N/A	N/A	Alphanumeric characters	0MddddL 0MddddL 0MddddL 0MddddL 0MddddL 0MddddL 0MddddL 0MddddL	11 – 18
5b	Emitter Category		Aircraft Identification – "Emitter Category"	6 – 8	38 - 40	8	N/A	N/A	discrete	000MdddL	19
5c	A/V Length and Width Codes	5	N/A	21 - 24	53 - 56	8	N/A	N/A	N/A	00000000	20
6	Emergency/Priority Status		Aircraft Status Message – Subtype 1 – "Emergency/Priority Status"	9 - 11	36 - 38	8	N/A	N/A	discrete	00000MbL	21
7	Capability Codes		Operational Status – "CC-4"	9 - 12	41 - 44	24	See Section N.4.4			00000000 dd000000 00000000	22 - 24
8	Operational Mode	4	N/A			16	N/A	N/A	N/A	00000000 00000000	25 - 26
9a	SV Quality - NACp		Airborne Position "Type Code" Surface Position "Type Code"	1 – 5 1 - 5	33 – 37 33 - 37	8	N/A	N/A	discrete	00000000	27
9b	SV Quality - NACv		Airborne Velocity Message –	11 - 13	43-45	8	N/A	N/A	discrete	00000MdL	28

Column #	REPORT STRUCTURE		MESSAGE STRUCTURE RELEVANT			REPORT STRUCTURE RELEVANT					
	1	2	3	4	5	6	7	8	9	10	11
Item #	**Parameter / Contents**	**Notes**	**Received Version 0 Message Sources**	**"ME" Field Bits**	**Message Field Bits**	**# of Bits**	**Range**	**Resolution**	**Units**	**Data Structure**	**Data Byte #**
			"NUC_R"								
9c	SV Quality – SIL	4, 5	Airborne Position – "Type Code" Surface Position – "Type Code"	1 – 5 1 - 5	33 – 37 33 - 37	8	N/A	N/A	discrete	000000ML	29
9d	SV Quality – BAQ (reserved)		N/A	N/A	N/A	8	N/A	N/A	discrete	000000ML	30
9e	SV Quality – NICbaro	4	N/A	N/A	N/A	8	N/A	N/A	discrete	0000000L	31
10a	Track/Heading and Horizontal Reference Direction (HRD)	4	Airborne Velocity – "SUBTYPE" - "Magnetic Heading Status Bit" Surface Position Message – "Status Bit for Ground Track"	6 - 8 14 13	38 - 40 46 45	8	N/A	N/A	discrete	0000000L	32
10b	Vertical Rate Type		Airborne Velocity – "Vert. Rate Source"	36	68	8	N/A	N/A	discrete	0000000L	33
11	Other (Reserved)		Reserved			8	Reserved			dddddddd	34
										TOTAL BYTES:	35

Notes for Table N-5:

1. *In the "Data Structure" column (i.e., column 10), "S" indicates the "sign-bit," "M" indicates the Most Significant Bit of the data field, "d" indicates data bits in the field, "L" indicates the Least Significant Bit of the data field, "0" indicates the bit is to always be set to a value of zero (0), and "x" indicates "Don't Care" bits in the data field.*

2. *If data is not available to support these fields, then the entire data field shall be set to ALL ZEROs.*

3. *The Report Type Identifier is used to identify the type of ADS-B Report being generated as defined in §2.2.8.1.1.1.*

4. *This parameter is not available for aircraft/vehicles broadcasting Version Zero (0) ADS-B Messages. If included in the Mode Status report the value of this parameter is to be set to all zeros otherwise it may be omitted from the Mode Status Report and its omission indicated in the Report Type and Structure Parameter using the format defined in Table 2.2.8.2.1.1.*

5. *This parameter is not available for aircraft/vehicles broadcasting Version Zero (0) ADS-B messages. This parameter is to be omitted from the Mode Status Report and its omission indicated in the Report Type and Structure Parameter using the format defined in Table 2.2.8.2.1.1.*

N.4.1 ADS-B Version

The format of the Aircraft Operational Status Message substantially differs between the Version Zero (0) ADS-B Message format shown in Figure N-7 and the Version One (1) ADS-B Message format specified in §2.2.3.2.7.3 of these MOPS. The Version One (1) Aircraft Operational Status Message format includes an explicit Version Number subfield (ME bits 41-43). For a Version Zero (0) ADS-B Aircraft Operational Status Message, these same bits are unassigned and are expected to be set to a value of ZERO (0). A Version One (1) ADS-B Receiving Subsystem will, as a default, assume the received messages are using Version Zero (0) ADS-B Message format unless, or until, an Aircraft Operational Status Message is received and the Version Number is confirmed to be other than Zero. However, in the case of a Version One (1) ADS-B Subsystem's reception of an Aircraft Operational Status Message, the ADS-B Receiving Subsystem will decode "ME" bits 41-43 and determine if the target aircraft is broadcasting messages that are ADS-B Version Zero (0) or Version One (1) and then decode the remainder of the message in accordance with the message format applicable to that Version Number.

Note: *The Version Number determined from the decoding of the Version Number subfield of the Aircraft Operational Status message must be retained and associated with the specific target since it is used in determining the applicable formats to be used for the decoding of the other message types.*

N.4.2 Emitter Category

The ADS-B Report Assembly Function will extract "TYPE" and "ADS-B Emitter Category" from the Aircraft Identification and Category Message (Figure N-3) and encode the "Emitter Category" field of the Mode Status Report as shown in Table 2.2.8.2.7. The Emitter Category conveyed in the Aircraft Identification and Category Message is mapped into the Mode Status Report, Emitter Category field as specified by Table 2.2.8.2.7. However, it must be noted that in the Version Zero (0) Aircraft Identification and Category Message, the Emitter Category subfield conveys a subset of the Emitter Categories allowed by the Mode Status Report.

N.4.3 A/V Length and Width Code

The A/V Length and Width Code is not conveyed by Version Zero (0) 1090 MHz ADS-B Messages. This parameter is only included in the Mode Status Report when reporting on an aircraft or vehicle that is on the airport surface. When no A/V Length and Wide Code is available, as is the case for target A/V that are broadcasting Version Zero (0) ADS-B Messages, the A/V Length and Wide Code parameter will not be included in the Mode Status Report and its omission so indicated in the Report Type and Structure Parameter using the coding specified in Table 2.2.8.2.1.1.

N.4.4 Emergency/Priority Status

The Emergency/Priority Status conveyed in the Aircraft Status Message (Figure N-6) will be directly mapped into the Mode Status Report, Emergency/Priority Status field as specified in §2.2.8.2.9. However, it must be noted that in the Version Zero (0) Aircraft

Extended Squitter Status Message, the Emergency/Priority Status subfield conveys a subset of the Emergency/Priority Status categories allowed by the Mode Status Report.

N.4.5 Capability Codes

The Version Zero (0) Operational Status Message (Figure N-7) conveys Control Codes with information limited to TCAS and CDTI capabilities, as shown in Table N-6. The Version Zero (0) Aircraft Operational Status Message format specifies coding only for the case of CC-4 (En Route Operational Capabilities). Therefore the CC-1, CC-2 and CC-3 subfields, as specified in Figure N-7, are to be considered reserved and not used for Version Zero (0) ADS-B Messages.

For the case of CC-4, this 4-bit (bits 9-12) subfield will be mapped to the Capability Code field of the Mode Status Report as shown in Table N-6. The remaining bits within the Mode Status Report Capability Code field will be set to Zero (0). If no Aircraft Operational Status Message has been received, then the Capability Code field may be omitted from the Mode Status Report and its omission so indicated in the Report Type and Structure Parameter using the coding specified in Table 2.2.8.2.1.1.

Table N-6: En-Route Operational Capabilities Encoding

CC-4 Encoding: En Route Operational Capabilities			
CC-4 Coding (Version Zero (0) Messages)		**Meaning (Version Zero (0) Messages)**	**Mapping to MS Report Capability Code field** CC Field Bits 11, 12
Bit 9,10	Bit 11,12		
0 0	0 0	TCAS Operational or unknown; CDTI not Operational or unknown	10
	0 1	TCAS Operational or unknown; CDTI Operational	11
	1 0	TCAS not Operational; CDTI not Operational or unknown	00
	1 1	TCAS not Operational; CDTI Operational	01

N.4.6 Operational Modes

Version Zero (0), RTCA DO-260 conformant, ADS-B Message formats do not define coding for the Operational Mode subfield of the operational status message. Therefore the OM-1, OM-2, OM-3 and OM-4 subfields, as shown in Figure N-7, are to be considered reserved and not used for ADS-B Version Zero (0) messages. Mode Status Reports for target aircraft/vehicles broadcasting Version Zero (0) ADS-B Messages will not include the Operational Mode field in the report and indicate the omission of this parameter in the Report Type and Structure Parameter using the coding specified in Table 2.2.8.2.1.1.

N.4.7 Navigation Accuracy Category for Position (NAC_P)

The Version Zero (0) ADS-B Surface and Airborne Position Messages have associated with each specific TYPE code a corresponding Horizontal Protection Limit and a 95%

Containment Radius (i.e., position error). For a Version One (1) ADS-B Receiving Subsystem, the TYPE codes of the received Version Zero (0) ADS-B Messages will be mapped into the value of the Navigation Accuracy Category for Position (NAC_P) as shown below in Table N-7 for the purpose of generating the Mode Status Report.

Table N-7: Type Code to NAC_P Mapping

Version 0 Message TYPE CODE	Message Format	Position Error (95%)	ADS-B MS Report NAC_P value
0	No Position Info	Unknown	0
5	Surface Position	< 3 m	11
6	Surface Position	< 10 m	10
7	Surface Position	< 0.05 NM	8
8	Surface Position	> 0.05 NM	0
9	Airborne Position	< 3 m	11
10	Airborne Position	< 10 m	10
11	Airborne Position	< 0.05 NM	8
12	Airborne Position	< 0.1 NM	7
13	Airborne Position	< 0.25 NM	6
14	Airborne Position	< 0.5 NM	5
15	Airborne Position	< 1 NM	4
16	Airborne Position	< 5 NM	1
17	Airborne Position	< 10 NM	1
18	Airborne Position	> 10 NM	0
20	Airborne Position	< 4 m	11
21	Airborne Position	< 15 m	10
22	Airborne Position	> 15 m	0

Note: *The Position Error column of the table indicates the greater of the horizontal or vertical 95% containment radius as listed in Table N-4 for Version Zero (0) messages.*

N.4.8 Navigation Accuracy Category for Velocity (NAC_V)

The Version Zero (0) ADS-B Airborne Velocity Message (see Figure N-4 and Figure N-5) includes a subfield that conveys the Navigation Uncertainty Category for Velocity (NUC_R). The received value of NUC_R will be mapped directly one-for-one to the Navigation Accuracy Category for Velocity (NAC_V) field of Mode Status Report.

N.4.9 Surveillance Integrity Level (SIL)

The Surveillance Integrity Level (SIL) defines the probability of the integrity containment region described by the NIC parameter being exceed for the selected geometric position source, including any external signals used by the source. The value of SIL can only be inferred from the information conveyed in Version Zero (0) ADS-B Messages. Table N-8 provides the mapping between the message Type Code for a Version Zero (0) transmitting system and the value of SIL to be reported by a Version One (1) receiving system within the Mode Status Report (see §2.2.8.2.14).

Table N-8: SIL Reporting

Version 0 Message TYPE CODE	Message Format	Integrity Level (probability of exceeding the horizontal containment radius (R_C) without an indication)	ADS-B MS Report SIL value
0	No Position Info	No Integrity	0
5	Surface Position	1 X 10^{-5} per flight hour or per sample	2
6	Surface Position	1 X 10^{-5} per flight hour or per sample	2
7	Surface Position	1 X 10^{-5} per flight hour or per sample	2
8	Surface Position	1 X 10^{-5} per flight hour or per sample	2
9	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
10	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
11	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
12	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
13	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
14	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
15	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
16	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
17	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
18	Airborne Position	No Integrity	0
20	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
21	Airborne Position	1 X 10^{-5} per flight hour or per sample	2
22	Airborne Position	No Integrity	0

N.4.10 Barometric Altitude Integrity Code (NIC_{BARO})

The Barometric Altitude Integrity Code (NIC_{BARO}) parameter of the Mode Status Report is a 1-bit flag used to indicate if the barometric altitude being reported in the State Vector Report has been cross-checked against another source of pressure altitude. The Version Zero (0) ADS-B Messages do not include information related to the cross-checking of barometric altitude. Therefore, Mode Status Reports for target aircraft/vehicles broadcasting Version Zero (0) ADS-B Messages will not include the NIC_{BARO} field in the report and therefore will indicate the omission of this parameter in the Report Type and Structure Parameter using the coding specified in Table 2.2.8.2.1.1.

N.4.11 Track/Heading and Horizontal Reference Direction (HRD)

Version Zero (0) Airborne Velocity Messages with SUBTYPE equal to 3 or 4 include a “Magnetic Heading Status Bit” as shown in Figure N-4. A 1090 MHz ADS-B Receiving Subsystem, upon receiving an Airborne Velocity Message with a Subtype of 3 or 4, must decode the Magnetic Heading Status Bit to determine if Magnetic Heading Data is “Available.” The ADS-B Receiving Subsystem will set the value of the True/Magnetic Heading subfield (see §2.2.8.2.17, of the Mode Status Report), as specified in Table N-9.

Table N-9: Track/Heading and HRD Subfield

Version 0 Airborne Velocity Message SUBTYPE	Airborne Velocity Message "Magnetic Heading Status Bit"	Surface Position Message "Ground Track Status Bit"	Meaning	ADS-B MS Report True/Magnetic Heading subfield coding Bits 1 - 0
N/A	N/A	0	No Valid Track/ Heading or Heading Direction Reference information available	00
1 or 2	N/A	1	Ground Track being reported	01
3 or 4	0	N/A	Heading relative to true north being reported	00
3 or 4	1	N/A	Heading relative to magnetic north being reported	11

Notes:

1. *When no valid data is available the "Track/Heading and HRD" parameter may be reported as ALL ZEROs, or omitted, from the Mode Status Report and the omission of this parameter indicated in the Report Type and Structure Parameter using the coding defined in Table 2.2.8.2.1.1.*

2. *As defined in §2.2.8.2.17, when receiving Version One (1) messages, the Track/Heading and HRD information are conveyed within the Operation Status Message. However, when receiving Version Zero (0) messages the equivalent information can be determined for airborne aircraft from the value of the "SUBTYPE" subfield and for Subtype=3 or 4 messages the value of the "Magnetic Heading Status Bit" of the Airborne Velocity Message (Figure N-4 and Figure N-5). When a target aircraft/vehicle is on the surface a value of 01 should be reported when a Surface Position Message (Figure N-2) is received with the "Ground Track Status Bit" set to a value of ONE (1) indicating that the valid ground track data is provided.*

3. *Version 0 Airborne Velocity Messages, Subtypes 3 and 4 always report Heading relative to Magnetic North, never relative to True North.*

N.5 Air Referenced Velocity Reports

The requirements of §2.2.8.3.2 for Air Referenced Velocity (ARV) Reports apply to the ARV Report Assembly requirements when the target aircraft is broadcasting either Version Zero (0) or Version One (1) ADS-B Message formats.

N.6 Target Status Reports

RTCA DO-260 defined a message format using message TYPE Code 29 to convey Aircraft Trajectory Intent information in the form of Trajectory Change Point (TCP) information. A 1090 MHz ADS-B Receiving Subsystem conforming to these MOPS (i.e., RTCA DO-242A) does not use any message with a TYPE Code of 29 that is received from a Version Zero (0) ADS-B Transmitting Subsystem for the purpose of report generation.

Note: *Prior to generation of a Target Status Report, the 1090 MHz ADS-B Receiving Subsystem must positively confirm that any received message with a TYPE Code of 29 has originated from a target aircraft with an ADS-B Version Number other than Zero (0). The ADS-B Version can be determined from the contents of the Version Number subfield of the Aircraft Operational Status Message (see §2.2.8.2.5 and §N.4.1).*

N.7 Formats for Version Zero (0) 1090 MHz ADS-B Messages

1090 MHz ADS-B Receiving Subsystems conformant to these MOPS (RTCA DO-260A) are required to receive and decode all Version One (1) compliant messages plus, for backward compatibility, must receive and decode certain messages types conforming to the previous RTCA DO-260, ADS-B Version Zero (0), formats. The following figures define the format of ADS-B Version Zero (0) Extended Squitter Messages that must be received and decoded and used for the generation of ADS-B reports as defined in §N.3 through §N.6.

Notes:

1. *In some cases, ARINC 429 labels are referenced for specific message fields. These references are only intended to clarify the field content, and are not intended as a requirement to use these ARINC 429 labels as the source for the message field.*

2. *The formats of the Version Zero (0) ADS-B Messages that are not required to be received and used for report generation by a Version One (1) 1090 MHz ADS-B receiving system are not shown in the following figures.*

Figure N-1: Extended Squitter Airborne Position Message

Bit	Field
1	
2	
3	FORMAT TYPE CODE
4	(See §N.2.1)
5	
6	SURVEILLANCE STATUS
7	
8	SINGLE ANTENNA FLAG (SAF)
9	
10	
11	ALTITUDE
12	Specified by the Format Type Code
13	
14	(1) the altitude code (AC) as specified
15	in §2.2.13.1.2 of DO-181D but
16	with the M-bit removed
17	(Ref ARINC 429 Label 203), or
18	
19	(2) GNSS height (HAE)
20	(Ref. ARINC 429 Label 370)
21	TIME (T)
22	CPR FORMAT
23	MSB
24	
25	
26	
27	
28	
29	
30	ENCODED LATITUDE
31	
32	(CPR Airborne Format)
33	
34	
35	
36	
37	
38	
39	LSB
40	MSB
41	
42	
43	
44	
45	
46	
47	ENCODED LONGITUDE
48	
49	(CPR Airborne Format)
50	
51	
52	
53	
54	
55	
56	LSB

Purpose: To provide accurate airborne position information

Surveillance Status coding
0 = no condition information
1 = permanent alert (emergency condition)
2 = temporary alert (change in Mode A identity code other than emergency condition)
3 = SPI condition

Codes 1 and 2 take precedence over code 3.

Note: *When horizontal position information is unavailable, but altitude information is available, the airborne position message is transmitted with a Format Type Code of ZERO in bits 1-5 and the barometric pressure altitude in bits 9 to 20. If neither horizontal position nor barometric altitude information is available, then all 56 bits of Register 05_{16} shall be ZEROed. The ZERO Format Type Code field indicates that latitude and longitude information is unavailable, while the ZERO altitude field indicates that altitude information is unavailable.*

Figure N-2: **Extended Squitter Surface Position Message**

1	
2	
3	FORMAT TYPE CODE
4	(See §N.2.1)
5	
6	
7	
8	
9	MOVEMENT
10	
11	
12	
13	STATUS for Gnd Tk (1 =valid, 0 = not valid)
14	MSB
15	
16	GROUND TRACK (7 bits)
17	
18	
19	**Resolution = 360/128 deg**
20	LSB
21	TIME (T
22	CPR FORMAT (F)
23	MSB
24	
25	
26	
27	
28	
29	
30	ENCODED LATITUDE
31	
32	(CPR Surface Format)
33	
34	
35	
36	
37	
38	
39	LSB
40	MSB
41	
42	
43	
44	
45	
46	
47	ENCODED LONGITUDE
48	
49	(CPR Surface Format)
50	
51	
52	
53	
54	
55	
56	LSB

Purpose: To provide accurate surface position information.

Figure N-3: Extended Squitter Aircraft Identification and Category Message

Bits	Field
1–5	FORMAT TYPE CODE (See §N.2.1)
6–8	AIRCRAFT CATEGORY
9 (MSB) – 14 (LSB)	CHARACTER 1
15 (MSB) – 20 (LSB)	CHARACTER 2
21 (MSB) – 26 (LSB)	CHARACTER 3
27 (MSB) – 32 (LSB)	CHARACTER 4
33 (MSB) – 38 (LSB)	CHARACTER 5
39 (MSB) – 44 (LSB)	CHARACTER 6
45 (MSB) – 50 (LSB)	CHARACTER 7
51 (MSB) – 56 (LSB)	CHARACTER 8

Purpose: To provide aircraft identification and category.

Type coding:

1 = Aircraft identification, category set D
2 = Aircraft identification, category set C
3 = Aircraft identification, category set B
4 = Aircraft identification, category set A

ADS-B Emitter Category coding:

Set A
0 = No ADS-B Emitter Category Information
1 = Light (< *15 500* lbs.)
2 = Small (*15 500* to 75 000 lbs.)
3 = Large (75 000 to 300 000 lbs.)
4 = High Vortex Large (aircraft such as B-757)
5 = Heavy (> 300 000 lbs.)
6 = High Performance (> 5 g acceleration and > 400kts)
7 = Rotorcraft

Set B
0 = No ADS-B Emitter Category Information
1 = Glider/sailplane
2 = Lighter-than-Air
3 = Parachutist/Skydiver
4 = Ultralight/hang-glider/paraglider
5 = Reserved
6 = Unmanned Aerial Vehicle
7 = Space/Trans-atmospheric vehicle

Set C
0 = No ADS-B Emitter Category Information
1 = Surface Vehicle – Emergency Vehicle
2 = Surface Vehicle – Service Vehicle
3 = Fixed Ground or Tethered Obstruction
4-7 = Reserved

Set D : Reserved

Aircraft identification coding:

Coding as specified for N.4.4

Figure N-4: Extended Squitter Airborne Velocity Message (Subtypes 1 and 2: Velocity Over Ground)

Bit				
1	MSB			**1**
2				**0**
3	FORMAT TYPE CODE = 19			**0**
4	(See §N.2.1)			**1**
5	LSB			**1**
6	SUBTYPE 1	0	SUBTYPE 2	0
7		0		1
8		1		0
9	INTENT CHANGE FLAG)			
10	IFR CAPABILITY FLAG			
11	NAVIGATION UNCERTAINTY			
12	CATEGORY – VELOCITY			
13	(NUC_R)			
14	DIRECTION BIT for E-W velocity **(0=East, 1=West)**			
15	EAST-WEST VELOCITY (10 bits)			
16	NORMAL : LSB = 1 knot		SUPERSONIC : LSB =4 knots	
17	All zeros = no velocity info		All zeros = no velocity info	
18	Value	Velocity	Value	Velocity
19	1	0 kts	1	0 kt
20	2	1 kt	2	4 kt
21	3	2 kt	3	8 kt
22	-	-	-	-
23	1022	1021 kt	1022	4084 kt
24	1023	>1021.5 kt	1023	> 4086kt
25	DIRECTION BIT for N-S velocity **(0=North, 1=South)**			
26	NORTH-SOUTH VELOCITY (10 bits)			
27	NORMAL : LSB = 1 knot		SUPERSONIC : LSB =4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kt
31	2	1 kt	2	4 kt
32	3	2 kt	3	8 kt
33	-	-	-	-
34	1022	1021 kt	1022	4084 kt
35	1023	>1021.5 kt	1023	> 4086kt
36	SOURCE BIT FOR VERTICAL RATE: 0 = Geometric, 1 = baro (1 bit)			
37	SIGN BIT FOR VERTICAL RATE: 0 = up, 1 = down			
38	VERTICAL RATE (9 bits)			
39	All zeros – no vertical rate information, LSB = 64 ft/min			
40	Value	Vertical rate	Ref. ARINC 429 labels	
41	1	0 ft/min	GPS: 165	
42	2	64 ft/min	INS: 365	
43	-	-		
44	510	32576 ft/min		
45	511	> 32608 ft/min		
46				
47	TURN INDICATOR (2 bits)			
48	TBD			
49	DIFFERENCE SIGN BIT (0 = above baro, 1 = below baro alt))			
50	GEOMETRIC HEIGHT DIFFERENCE FROM BARO. ALT. (7 bits)			
51	All zeros = no info; LSB = 25 ft			
52	Value	Difference		
53	1	0 ft		
54	2	25 ft		
55	-	-		
56	126	3125 ft		
	127	> 3137.5 ft		

Purpose: To provide additional state information for both normal and supersonic flight.

Subtype Coding

Code	Velocity	Type
0	As in first edition of the ICAO Manual on Mode S Specific Services	
1	Ground speed	normal
2		supersonic
3	Airspeed, heading	normal
4		supersonic
5	Not assigned	
6	Not assigned	
7	Not assigned	

IFR Capability Flag coding:

0 = Transmitting aircraft has no capability for applications requiring ADS-B equipage class A1S/A1 or above

1 = Transmitting aircraft has capability for applications requiring ADS-B equipage class A1S/A1 or above.

Ref. ARINC Labels for Velocity:

East-West	North-South
GPS: 174	GPS: 166
INS: 367	INS: 366

Ref. ARINC Labels
GNSS Height (HAE): GPS: 370
GNSS Altitude (MSL): GPS: 076

Navigation Uncertainty Category:

$HFOM_R$ value		$VFOM_R$ value	NUC_R value
$HFOM_R$ < 0.3 m/s (0.984 fps)	AND	$VFOM_R$ < 0.46 m/s (1.5 fps)	4
$HFOM_R$ < 1 m/s (3.28 fps)	AND	$VFOM_R$ < 1.5 m/s (5.0 fps)	3
$HFOM_R$ < 3 m/s (9.84 fps)	AND	$VFOM_R$ < 4.6 m/s (15.0 fps)	2
$HFOM_R$ < 10 m/s (32.8 fps)	AND	$VFOM_R$ < 15.2 m/s (50 fps)	1
$HFOM_R$ unknown or $HFOM_R$ ≥10 m/s (32.8 fps)	OR	$VFOM_R$ unknown or $VFOM_R$ ≥ 15.2 m/s (50 fps)	0

Figure N-5: Extended Squitter Airborne Velocity Message (Subtypes 3 and 4: Airspeed and Heading)

Bit	Field			
1	MSB			**1**
2				**0**
3	FORMAT TYPE CODE = 19			**0**
4	(See §N.2.1)			**1**
5	LSB			**1**
6	SUBTYPE 3	0	SUBTYPE 4	1
7		1		0
8		1		0
9	INTENT CHANGE FLAG**)**			
10	IFR CAPABILITY FLAG			
11	NAVIGATION UNCERTAINTY			
12	CATEGORY – VELOCITY			
13	(NUC_R)			
14	STATUS BIT – 1 = Magnetic heading available, 0 = not available			
15	MSB			
16				
17				
18	MAGNETIC HEADING (10 bits)			
19	(§N.4.5.5)			
20				
21				Ref. ARINC 429 Label:
22				INS: 320
23	Resolution = 360/1024 deg			
24	LSB			
25	AIRSPEED TYPE: 0 = IAS, 1 = TAS			
26	AIRSPEED (10 bits)			
27	NORMAL : LSB = 1 knot		SUPERSONIC : LSB =4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kt
31	2	1 kt	2	4 kt
32	3	2 kt	3	8 kt
33	-	-	-	-
34	1022	1021 kt	1022	4084 kt
35	1023	>1021.5 kt	1023	> 4086 kt
36	SOURCE BIT FOR VERTICAL RATE: 0 = Geometric, 1 = baro (1 bit)			
37	SIGN BIT FOR VERTICAL RATE: 0 = up, 1 = down			
38	VERTICAL RATE (9 bits)			
39	All zeros – no vertical rate information			
40	LSB = 64 ft/min			
41	Value	Vertical rate	Ref. ARINC labels	
42	1	0 ft/min	GPS: 165	
43	2	64 ft/min	INS: 365	
44	-	-		
45	510	32576 ft/min		
46	511	> 32608 ft/min		
47	TURN INDICATOR (2 bits)			
48	TBD			
49	DIFFERENCE SIGN BIT (0 = above baro, 1 = below baro alt))			
50	GEOMETRIC HEIGHT DIFFERENCE FROM BARO. ALT. (7 bits)			
51	All zeros = no info; LSB = 25 ft			
52	Value	Vertical rate	Ref. ARINC 429 labels	
53	1	0 ft		
54	2	25 ft		
55	-	-		
56	126	3125 ft		
	127	> 3137.5 ft		

Purpose: To provide additional state information for both normal and supersonic flight based on airspeed and heading.

Note: *This format is only used if velocity over ground is not available*

See the definition of NUC_R in DO-260 §2.2.3.2.6.1.5.

Subtype Coding

Code	Velocity	Type
0	As in first edition of the ICAO Manual on Mode S Specific Services	
1	Ground speed	normal
2		supersonic
3	Airspeed, heading	normal
4		supersonic
5	Not assigned	
6	Not assigned	
7	Not assigned	

IFR Capability Flag coding:

0 = Transmitting aircraft has no capability for applications requiring ADS-B equipage class A1S/A1 or above

1 = Transmitting aircraft has capability for applications requiring ADS-B equipage class A1S/A1 or above.

Ref. ARINC 429 Labels for Air Data Source:
IAS: 206
TAS: 210

Figure N-6: Extended Squitter Aircraft Status Message (Subtype 1: Emergency/Priority Status)

1 2 3 4 5	FORMAT TYPE CODE = 28 (See §N.2.1)
6 7 8	Subtype Code = 1
9 10 11	EMERGENCY/PRIORITY STATUS (3 bits)
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56	RESERVED

Purpose. To provide additional information on aircraft status.

Subtype Coding:

0	=	No Information
1	=	Emergency/Priority Status
2-7	=	Reserved

Emergency/Priority Status Coding

Value	*Meaning*
0	No emergency
1	General emergency
2	Lifeguard/medical
3	Minimum fuel
4	No communications
5	Unlawful interference
6	Reserved
7	Reserved

Notes:

1. *Message delivery is accomplished once per second using the event driven protocol.*
2. *Termination of emergency state is detected by coding in the surveillance status field of the airborne position message.*

Figure N-7: Aircraft Operational Status Message

1	MSB
2	
3	FORMAT TYPE CODE = 31
4	(See §N.2.1)
5	LSB
6	MSB
7	SUBTYPE Code = 0
8	LSB
9	MSB
10	En-Route Operational Capabilities (CC-4)
11	
12	LSB
13	MSB
14	Terminal Area Operational Capabilities(CC-3)
15	
16	LSB
17	MSB
18	Approach/ Landing Operational Capabilities (CC-2)
19	
23	LSB
21	MSB
22	Surface Operational Capabilities (CC-1)
23	
24	LSB
25	MSB
26	Enroute Operational Capability Status (OM –4)
27	
28	LSB
29	MSB
30	Terminal Area Operational Capability Status (OM-3)
31	
32	LSB
33	MSB
34	Approach/ Landing Operational Capability Status (OM-2)
35	
36	LSB
37	MSB
38	Surface Operational Capability Status (OM-1)
39	
40	LSB
41	
42	
43	
44	
45	
46	
47	
48	Not Assigned
49	
50	
51	
52	
53	
54	
55	
56	

Purpose: To provide the Capability Class and Current Operational Mode Of ATC related applications On board the aircraft.

Appendix O

Accommodation of Trajectory Change Reporting

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O Accommodation of Trajectory Change Reporting

O.1 Introduction

In addition to the ADS-B requirements on which these MOPS are based, RTCA DO-242A also provides a description of additional intent communications for which future requirements are being considered. Trajectory Change (TC) Reports are defined, although operational applications and resulting broadcast requirements are still under development. Anticipating the possible use of TC Reports in the future, this Appendix provides corresponding specifics for implementing this communication using Extended Squitter. The analysis in this Appendix assumes that all communications of intent information will be non-addressed air-to-air broadcasts. However, it should be noted that as applications are developed that require long-range intent information, especially data supporting reports beyond TC+1, it is quite possible that information will be transmitted air-to-ground and/or in addressed communications such as the Mode S interrogation-reply data link between transponder equipped aircraft and radar ground stations.

TC Reports are an extension to the Trajectory Change Point (TCP) reporting that was described in both RTCA DO-242 and RTCA DO-260. During the update to the ADS-B MASPS to version RTCA DO-242A it was concluded that the previously defined TCP reporting provisions were not sufficient for the intended purpose. The preliminary requirements reflected in RTCA DO-242A for TC Reports are intended to accommodate a variety of airborne capabilities. Thus, some aircraft may broadcast only a subset of the TC information allowed for by RTCA DO-242A in the TC Report structure. Section 2.1.2.19.2 of RTCA DO-242A describes the operational requirements for TC Reporting and §3.4.8 of RTCA DO-242A provides the technical and performance requirements for TC Reporting. RTCA DO-242A does not define the minimum set of TC related parameters that must be broadcast. RTCA DO-242A defines preliminary requirements for reporting of information related to the first through forth point at which the aircraft trajectory will change. The associated reports are designated as TC+0, TC+1, TC+2 and TC+3 reports. RTCA DO-242A suggests that additional TC Reports may ultimately be defined. This Appendix specifically addresses only the accommodation of TC+0 and TC+1 reports with an indication of the potential support for additional TC Reports.

O.2 Summary of Trajectory Change Reporting Requirements

RTCA DO-242A, Table 3-24 defines the content requirements for TC+0 and TC+n Reports. The broadcast of messages supporting TC+0 Reports will be required for all Class A2 and Class A3 ADS-B equipped aircraft, as per RTCA DO-242A, Table 3-3(a). The broadcast of messages supporting TC+n Reports would only be required of Class A3 ADS-B equipped aircraft, as per RTCA DO-242A, Table 3-3(a). Table O-1 below defines the requirements for TC Report content is a simplified version derived from the Table 3-24 of RTCA DO-242A.

Table O-1: Proposed Trajectory Change (TC) Report Definition

	TC Report Elem. #	Contents [Notes]	[Resolution or # of Bits]	Needed Only For TC+0 Reports
ID	1	Participant Address	[24 bits]	
	2	Address Qualifier	[1 bit]	
TOA	3	Time of Applicability	[1 s resolution]	
TC Report #	4	TC Report Sequence Number	[2 bits]	
TC Report Version	5a	TC Report Cycle Number	[2 bits]	
	5b	(Reserved for TC Management Indicator)	[3 bit]	•
TTG	6	Time To Go	[4 s resolution]	
Horizontal TC Report Information	7a	Horizontal Data Available and Horizontal TC Type	[4 bits]	
	7b	TC Latitude	[700 m or better]	
	7c	TC Longitude	[700 m or better]	
	7d	Turn Radius	[700 m or better]	
	7e	Track to TCP	[1 degree]	
	7f	Track from TCP	[1 degree]	
	7g	(Reserved for Horizontal Conformance)	[1 bit]	•
	7h	Horizontal Command/Planned Flag	[1 bit]	
Vertical TC Report Information	8a	Vertical Data Available and Vertical TC Type	[4 bits]	
	8b	TC Altitude	[100 ft resolution]	
	8c	TC Altitude Type	[1bit]	
	8d	(Reserved for Altitude Constraint Type)	[2 bits]	
	8e	(Res. for Able/Unable Altitude Constraint)	[1 bit]	•
	8f	(Reserved For Vertical Conformance)	[1 bit]	•
	8g	Vertical Command/Planned Flag	[1 bit]	

O.3 1090 MHz ADS-B Message for Trajectory Change Information

The Trajectory Change information will be broadcast from the aircraft using a Trajectory Change (TC) Message. Message TYPE Code 27 has been reserved for this purpose as indicated in Table 2-11 of these MOPS. For Message TYPE Code 27 a 2-bit SUBTYPE subfield will be defined with 4 codes reserved for conveying the Trajectory Change information associated with TC+0 and TC+1 Reports (as required by RTCA DO-242A). The TYPE Code plus the SUBTYPE subfield would occupy the first 7 bits of the 56-bit ME field of the extended squitter. This results in the 49 remaining bits being available to convey the Trajectory Change information. With this limitation on the transmission frame size, the broadcast of Trajectory Change information will need to be segmented. Two Trajectory Change Messages will be required to convey the complete set of Trajectory Change information defined for a complete TC+0 or a TC+n Report.

The preliminary concept would be to define the 4 Message SUBTYPES as shown in Table O-2.

Table O-2: Proposed TC Message SUBTYPE Values

SUBTYPE = 00	TC+0 Basic Information
SUBTYPE = 01	TC+1 Basic Information
SUBTYPE = 10	1st Supplemental Message
SUBTYPE = 11	2nd Supplemental Message

For SUBTYPEs 00 and 01 there would be 49 bits available to convey the basic information needed for generation of TC+0 and TC+1 reports. SUBTYPEs 10 and 11 would be used for TC Messages that convey the additional information necessary to generate a TC+0 or a TC+1 Reports that is beyond the basic TC information being conveyed in the SUBTYPE=00 or 01 Messages. The TC Message format for conveying TC supplemental information will use the TC Report Sequence Number and the TC Report Cycle Number to allow the Supplemental TC information to be correctly associated the intended Basic TC Messages.

If the TC Basic Message can support the minimum application requirements for the TC Report, and can therefore be transmitted without an associated TC Supplement Message, a means conveying whether or not TC Supplemental Messages are being broadcast must be provided. (Possible means include coding schemes within TC Basic Messages, or within Operational Status Messages.)

Table O-3 shows how the information required for a TC+0 and TC+1 reports would be conveyed by the 1090 MHz ADS-B Messages.

It is proposed that if TC+3 or subsequent Trajectory Change points are desired, with the 1090 MHz system, these would be supported only as an addressed air-ground service and would not be supported as a broadcast service using Extended Squitter.

Table O-3: Bit Allocation for Messages Supporting Trajectory Change Reports

	TC Report Element #	Contents	How conveyed by 1090 MHz ADS-B Messages	Trajectory Change Message SUBTYPEs		
				TC+0 Basic	TC+1 Basic	Supplemental TC
ID	1	Participant Address	Conveyed in Message Header	0 bits	0 bits	0 bits
	2	Address Qualifier	Conveyed in Aircraft ID and Category Message	N/A	N/A	N/A
TOA	3	Time of Applicability	Added by Receiver	N/A	N/A	N/A
TC Report #	4	TC Report Sequence Number (conveyed by the SUBTYPE Code)	TYPE 27 ADS-B Message	2 bits	2 bits	2 bits
TC Report Version	5a	TC Report Cycle Number	TYPE 27 ADS-B Message	2 bits	2 bits	2 bits
	5b	(Reserved for TC Management Indicator)	TYPE 27 ADS-B Message	N//A	N/A	[note 1]
TTG	6	Time To Go	TYPE 27 ADS-B Message	9 bits	9 bits	N/A
Horizontal TC Report Information	7a	Horizontal Data Available and Horizontal TC Type	TYPE 27 ADS-B Message	3 bits [note 2]	3 bits [note 2]	N/A [note 2]
	7b	TC Latitude	TYPE 27 ADS-B Message	10 bits	10 bits	N/A
	7c	TC Longitude	TYPE 27 ADS-B Message	10 bits	10 bits	N/A
	7d	Turn Radius	TYPE 27 ADS-B Message	N/A	N/A	7 bits
	7e	Track to TCP	TYPE 27 ADS-B Message	N/A	N/A	9 bits
	7f	Track from TCP	TYPE 27 ADS-B Message	N/A	N/A	9 bits
	7g	(Reserved for Horizontal Conformance)	TYPE 27 ADS-B Message	N/A	N/A	[note 1]
	7h	Horizontal Command/Planned Flag	TYPE 27 ADS-B Message	1 bit	1 bit	N/A
Vertical TC Report Information	8a	Vertical Data Available and Vertical TC Type	TYPE 27 ADS-B Message	3 bits [note 2]	3 bits [note 2]	N/A
	8b	TC Altitude	TYPE 27 ADS-B Message	10 bits	10 bits	N/A
	8c	TC Altitude Type	TYPE 27 ADS-B Message	1 bit	1 bit	N/A
	8d	(Reserved for Altitude Constraint Type)	TYPE 27 ADS-B Message	N/A	N/A	[note 1]
	8e	(Reserved for Able/Unable Altitude Constraint)	TYPE 27 ADS-B Message	N/A	N/A	[note 1]
	8f	(Reserved For Vertical Conformance)]	TYPE 27 ADS-B Message	N/A	N/A	[note 1]
	8g	Vertical Command/Planned Flag	TYPE 27 ADS-B Message	N/A	N/A	1 bit
Spare Bits				0	0	19
ME Bits for TYPE Code				5	5	5
TOTAL ME Bits				56	56	56

Notes:

1. *Report elements indicated by RTCA DO-242A as reserved are not assigned bits. If required by a future ADS-B MASPS revision, such report elements would be accommodated within a Supplemental TC Message using the "spare" bits.*
2. *Although RTCA DO-242A assumes 4 bits are provided for this parameter, less than eight values were assigned by RTCA DO-242A with the remainder being reserved. In order to provide the most efficient use of the 1090 MHz ADS-B Message structure, the allowed values for this parameter within the TC+0 and TC+1 Messages will be restricted to the range of 0 to 7, requiring only 3 bits for encoding. If in the future a need arises that requires values that cannot be accommodated within 3 bits, then a binary value of "111" could be used to indicate that the value of the parameter is 7 or greater, and the specific value would then be included in the Supplemental TC Message.*

O.4 Transmission Rate Requirements

RTCA DO-242A does not define a specific update rate requirement for TC+0 or TC+1 Reports. However, RTCA DO-242A, Appendix N provides an estimate for TC+0 Reports where air-to-air update rates are range dependent. RTCA DO-242A, Table N-8 defines a nominal update interval at 95% probability for TC+0 Reports as:

Range < 20 NM --- Update Interval = 12 seconds (Class A2 and A3 systems)
Range = 40 NM --- Update Interval = 18 seconds (Class A2 and A3 systems)
Range = 90 NM --- Update Interval = 41 seconds (Class A3 systems)

RTCA DO-242A, Table N-8 also defines a 12-second update interval following a TC+0 state change at ranges to 40 NM.

No update rates are provided for air-to-ground delivery of TC information, nor is the role of the ground ATM system adequately considered in the operational concept presented in the RTCA DO-242A, Appendix N.

The 1090 MHz ADS-B TC Messages required to support conveying the complete information defined by RTCA DO-242A for a TC+0 Report includes both the TC+0 Basic and the 1st Supplemental TC Messages. However, it may be possible to transmit the TC+0 Basic Message at a higher rate than the TC Supplemental Message since the TC+0 Basic Message provides the most essential information and a small delay in receiving updates to the supplemental information may be acceptable. It is also probable that some or perhaps many Class A2 and A3 aircraft will not be equipped to provide other than the Basic TC information. In this case, if it is operationally determined that this information is satisfactory to support the desired applications, then the Supplemental TC Message would not be required. It is not possible at this time to establish the specific update rate requirements for the individual data elements defined by RTCA DO-242A for the TC+0 Reports. As the operational concepts and definition of applications that use TC Reports mature, this may become possible. The other 1090 MHz ADS-B Messages and their associated nominal broadcast rates that will routinely be broadcast for an Airborne Class A2 or A3 system are:

Position:	2.0 per second
Velocity:	2.0 per second
AC ID & Type:	0.2 per second
Operational Status:	0.4 per second
Target State:	0.8 per second
Total:	5.4 per second

These MOPS, as well as the Mode S Transponder MOPS (RTCA DO-181D), limit the total transmission rate of all Extended Squitters to 6.2 per second. This means that if implemented under the current overall rate limit of 6.2 squitters per second, the broadcast of Trajectory Change information would need to be limited to not more than 0.8 messages per second. Given this current overall limit of 6.2 squitters per second, only TC+0 can be considered and supported. Support for TC+1 Messages will require an increase in the overall rate limit. Since the complete set of TC information requires both a Basic TC Message plus a TC Supplemental Message, there are two alternatives:

1. Broadcast both the Basic TC+0 Message and the associated Supplemental TC Message at a rate of 0.4 (i.e., at 2.5 second intervals).

2. If it is deemed appropriate to update the data elements contained in the Supplemental TC Message at a lower rate than the information included in the Basic TC+0 Message, then it may be appropriate to broadcast the Basic TC+0 Message at perhaps 0.5 messages per second and the TC+0 Supplemental Message at perhaps a rate of 0.3 messages per second.

As indicated above, there may be many aircraft that are only capable of broadcasting the information included in the Basic TC Message (i.e., TC Supplemental Message not being broadcast), in which case the Basic TC Message could be broadcast at the rate of 0.8 messages per second.

Even support for TC+0 could be enhanced by allowing for a total Extended Squitter broadcast rate above the current limit of 6.2 squitters per second. Ideally, the TC+0 related messages, or at least the Basic TC+0 Message would be broadcast at the same rate as that used for the Target State Messages (0.8 per second). If both of the TC+0 Supplemental Messages were each to be broadcast at 0.8 per second, then the maximum Extended Squitter broadcast rate would need to be raised to 7 per second for those aircraft equipped to provide the full set of TC information.

Accommodating both the TC+0 and TC+1 related messages will require that the maximum allowed Extended Squitter rate be increased to at least 7 squitters per second and more realistically to perhaps on the order of 8 squitters per second.

These above suggested maximum rates are considered appropriate to satisfy the RTCA DO-242A preliminary requirements and estimates for aircraft-to-aircraft reporting of Trajectory Change information in moderate to perhaps high density airspace (at up to 40 NM). In low density airspace the reception probabilities increase because of lower 1090 MHz fruit rates and as a result, more modest transmission rates would suffice to support the required reception ranges and TC Report update rates.

O.5 Estimated Performance

O.5.1 TC+0 Performance Estimate

There are many factors that will impact the ability of the 1090 MHz ADS-B system to deliver Trajectory Change information. As discussed above in §O.4 there are a number of alternatives as to the rate at which TC+0 messages are broadcast. The broadcast rate will depend on both the aircraft equipage (e.g., only able to provide basic TC information versus more extensive TC information) and also on the ability to revise the Mode S transponder standards, both within RTCA and ICAO, to permit an increase in the peak transmission rates for Extended Squitters. The full set of TC+0 Report information must be split into two Extended Squitter Messages for transmission. For the case where a given aircraft is only capable of providing the information contained in the Basic TC+0 Message, reception of this single message type will be sufficient to generate an TC+0 Report. For the case of an aircraft equipped to provide the full TC+0 information set, then the reception of both a Basic TC+0 and a Supplemental TC+0 Message would be required in order to update the TC+0 Report.

Given these uncertainties and potential variations in the broadcast capabilities, estimates were developed for three alternative cases for the broadcast of TC+0 Messages. Simulations runs have not been specifically conducted for these alternative cases. Rather a simplified approach was employed where the per squitter reception probability was calculated that would be required to satisfy the RTCA DO-242A, Appendix N guidance material for TC+0 Report nominal update rates. The simulation results were then reviewed to estimate at what range the calculated per squitter reception probability would be supported. Since two different simulations were used to estimate the performance, both the results from the Johns Hopkins-APL simulations and the results from the MIT Lincoln Laboratory simulations are provided. These simulations are described in Appendix P of these MOPS. The simulation results are presented for both a low density traffic environment as well as the postulated future Los Angles traffic environment for the year 2020. The LA2020 scenario with 24,000 Mode A/C fruit per second interference level was used for the analysis of TC reception performance in a high density environment. The effects of increased loading on the 1090 MHz channel from the increased rate of Extended Squitter transmissions that would be necessary to accommodate TC Reporting have not been considered in the analysis. The effect of the increased channel loading is expected to be minor for the case where the total Extended Squitter transmission rate is limited to 6.2 squitters per second. As the requirements for TC Reporting mature, further studies should be conducted to determine an appropriate upper limit on Extended Squitter transmission rates and under what conditions such maximum transmission rates would be permitted.

Note that the applicability of TC reporting is currently limited within RTCA DO-242A to air-to-air ranges of up to 40 NM within high density airspace as represented by the LA2020 scenario, and up to 90 NM in low density airspace. RTCA DO-242A does note, however, that “the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.”

RTCA DO-242A also proposed increased reporting rates following a change in certain elements of the TC Reports. The 1090 MHz ADS-B system could accommodate this by temporarily lowering the broadcast rate of lower priority messages. This is supported by the message scheduling function defined in these MOPS. However, the potential requirement for increased TC+0 reporting rates following a change in TC information is not specifically considered in the following performance analysis (i.e., only the nominal TC+0 reporting case is considered).

Case 1 –

The first case to be considered is that in which only the Basic TC+0 Message is being broadcast. In this case it is assumed that the TC+0 Messages would be broadcast at the same rate as used for the Target State and Status Messages (i.e., 0.8 messages per second). In order to support the ADS-B MASPS guidance for TC+0 Report updates at 95% probability, the nominal required per message reception probability is described by the formula: $0.95 = 1 - (1-P_{message})^N$ or rewriting for calculating the necessary per squitter reception probability: $P_{message} = 1 - (1 - 0.95)^{1/N}$ where **N** is the number of transmissions within the required received update interval. The following table indicates the per message reception probability needed to satisfy the RTCA DO-242A guidance for the nominal air-to-air reporting of TC+0 information at ranges of 20, 40 and 90 NM.

Table O-4: Case 1 – TC Message Reception Probability

Air-Air Range	TC+0 Report Nominal Update Rate	"Required" Message Reception Probability
20 NM	12 Seconds	26.8%
40 NM	18 Seconds	18.8%
90 NM	41 Seconds	8.7%

In **Case 1**, the effective reporting rate for TC+0, in which only a Basic TC+0 Message is being broadcast, would be essentially the same as for TS Reports as described in Appendix P. The estimated TC+0 reporting rate is summarized in the Table O-5 and Figures O-1, O-2 and O-3 for the LA2020 and low traffic density scenarios. These performance estimates are for the case of Class A3 receiving systems.

Table O-5: Case 1 – TC Report Performance

TC+0 Report Update Rate	Estimated Air-Air Range for Low Density Scenario (A3 Tx -to- A3 Rx)		Estimated Air-Air Range LA2020 Scenario (A2 Tx -to- A3 Rx)		Estimated Air-Air Range LA2020 Scenario (A3 Tx -to- A3 Rx)	
	APL	**LL**	**APL**	**LL**	**APL**	**LL**
12 Sec.	90 NM	115 NM	30 NM	24 NM	40 NM	30 NM
18 Sec.	110 NM	123 NM	30 NM	32 NM	40 NM	40 NM
41 Sec.	120 NM	132 NM	50 NM	52 NM	60 NM	65 NM

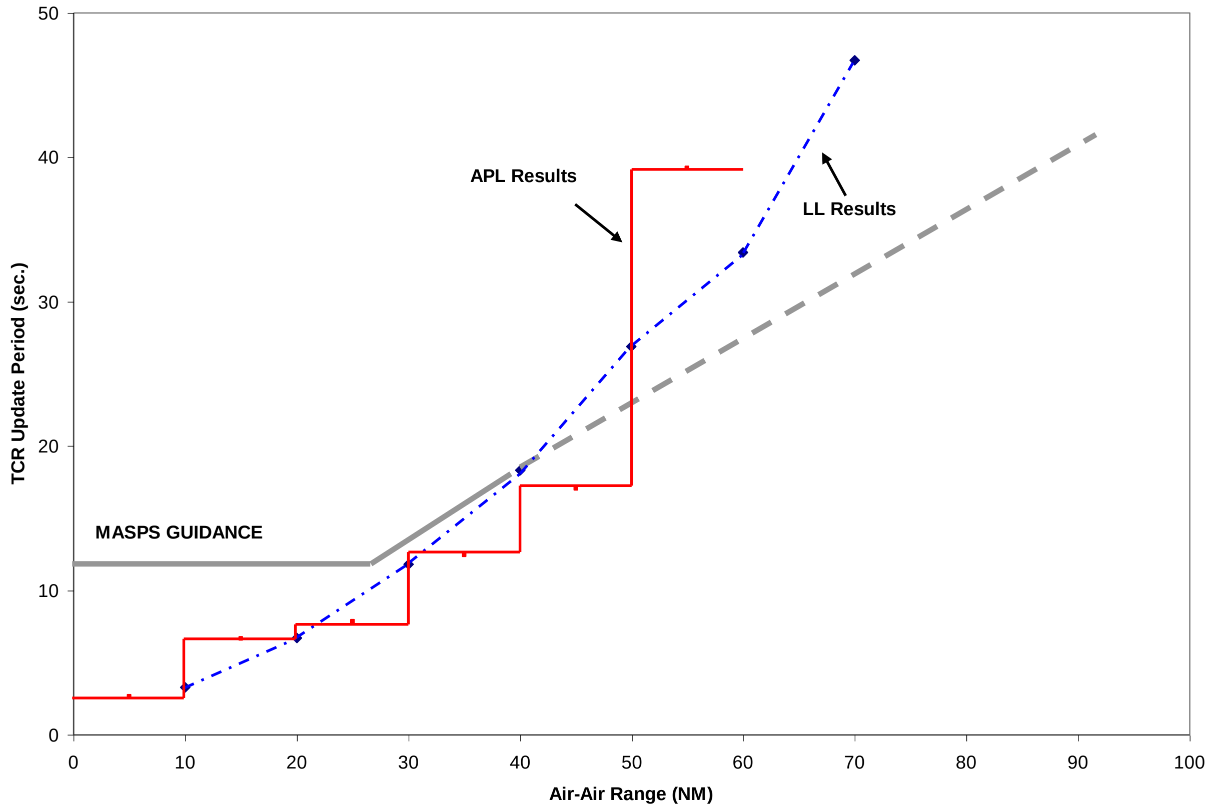
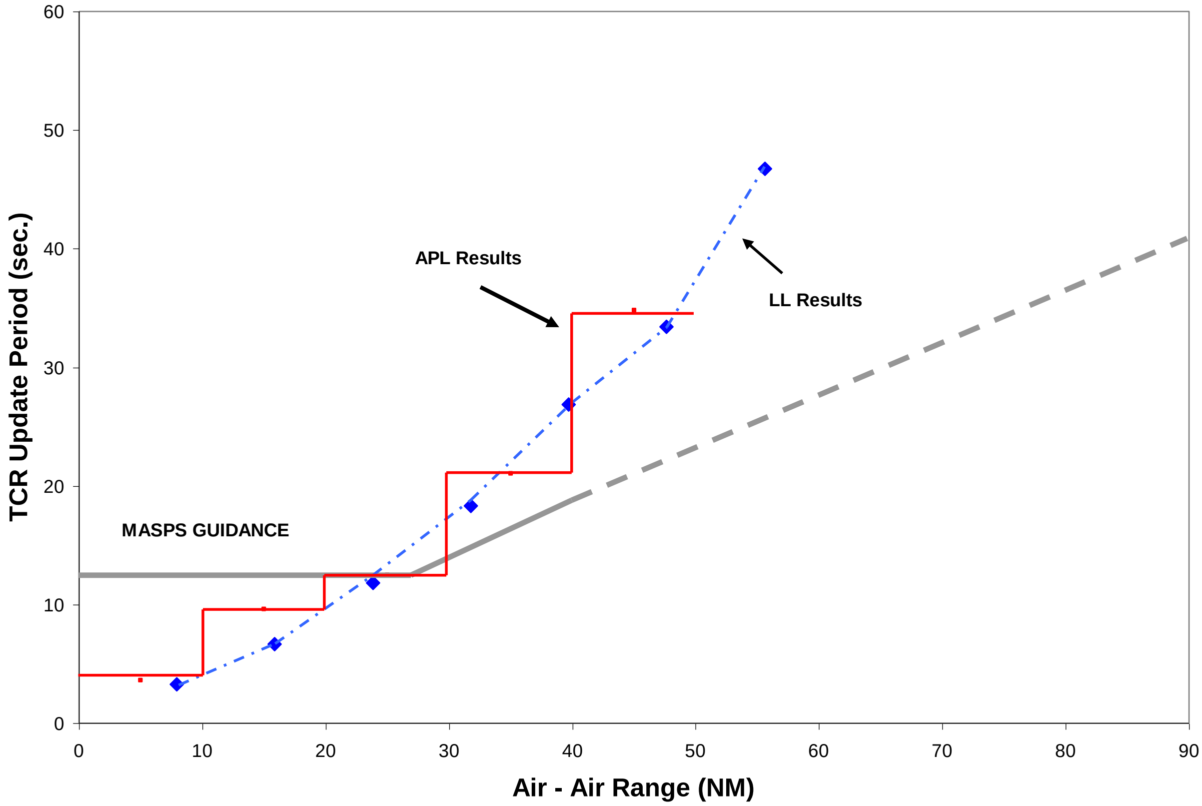


Figure O-1: Case 1 – LA2020-[24k] for A3 Tx -to- A3 Rx



<u>Figure O-2:</u> Case 1 – LA2020-[24k] for A2 Tx -to- A3 Rx

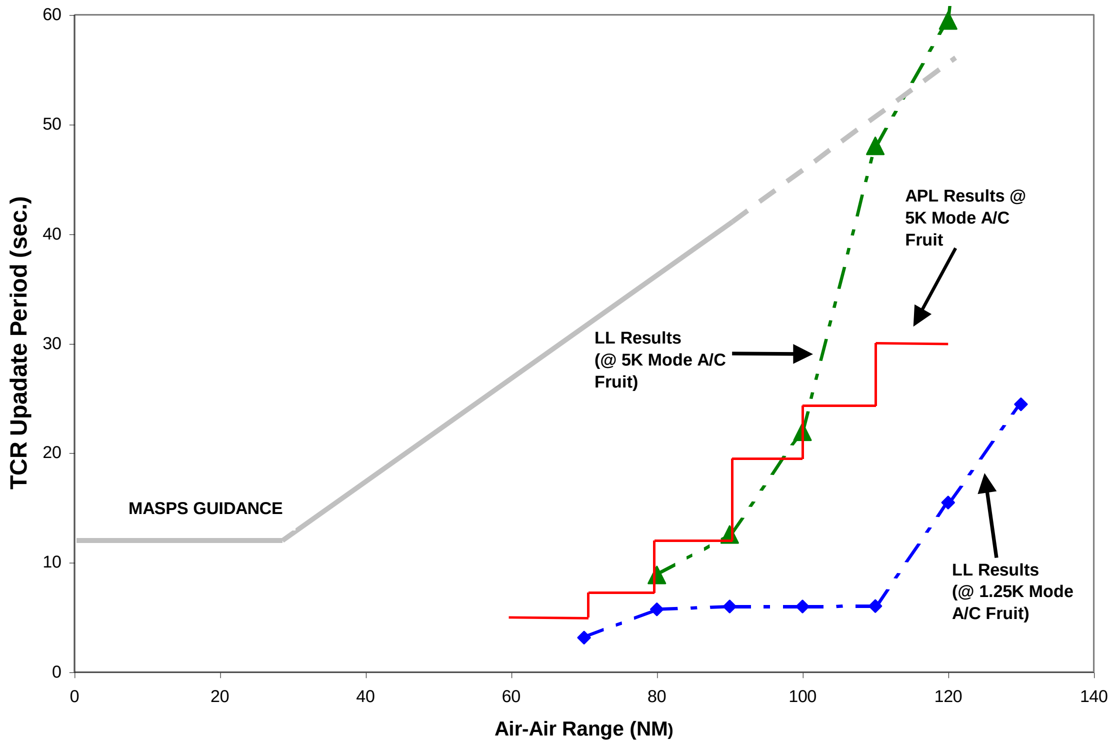


Figure O-3: Case 1 – Low Density A3 Tx -to- A3 Rx

Case 2 –

For **Case 2**, the full TC+0 information set is split between a Basic and a Supplemental TC+0 Message and each message is broadcast at the rate of 0.8 messages per second. This case would only be possible if the allowed peak Extended Squitter broadcast rate were increased to 7 Extended Squitters per second or greater. In order to support the ADS-B MASPS guidance for TC+0 Report updates at 95% probability the nominal required per message reception probability is described by the formula: $0.95 = [1 - (1-P_{message})^N]^2$ or rewriting for calculating the necessary per squitter reception probability: $P_{message} = 1 - [1- (0.95)^{1/2}]^{1/N}$ where **N** is the number of transmissions within the required received update interval. Table O-6 indicates the per message reception probability needed to satisfy the RTCA DO-242A guidance for the nominal air-to-air reporting of TC+0 information at ranges of 20, 40 and 90 NM.

Table O-6: Case 2 – TC Message Reception Probability

Air-Air Range	TC+0 Report Nominal Update Rate	"Required" Message Reception Probability
20 NM	12 Seconds	31.1%
40 NM	18 Seconds	22.5%
90 NM	41 Seconds	10.6%

In **Case 2**, the effective reporting rate for TC+0 information, in which both a Basic TC+0 Message and a Supplemental TC+0 Message is being broadcast, the estimated TC+0 reporting rate is summarized in Table O-7 and Figure O-4, Figure O-5 and Figure O-5 for the LA2020 and the low traffic density scenarios for the case of Class A3 receiving systems.

Table O-7: Case 2 – TC Report Performance

TC+0 Report Update Rate	Estimated Air-Air Range for Low Density Scenario (A3 Tx -to- A3 Rx)		Estimated Air-Air Range LA2020 Scenario (A2 Tx -to- A3 Rx)		Estimated Air-Air Range LA2020 Scenario (A3 Tx -to- A3 Rx)	
	APL	**LL**	**APL**	**LL**	**APL**	**LL**
12 Sec.	90 NM	112 NM	20 NM	21 NM	30 NM	27 NM
18 Sec.	100 NM	120 NM	30 NM	28 NM	40 NM	35 NM
41 Sec.	120 NM	131 NM	40 NM	48 NM	50 NM	60 NM

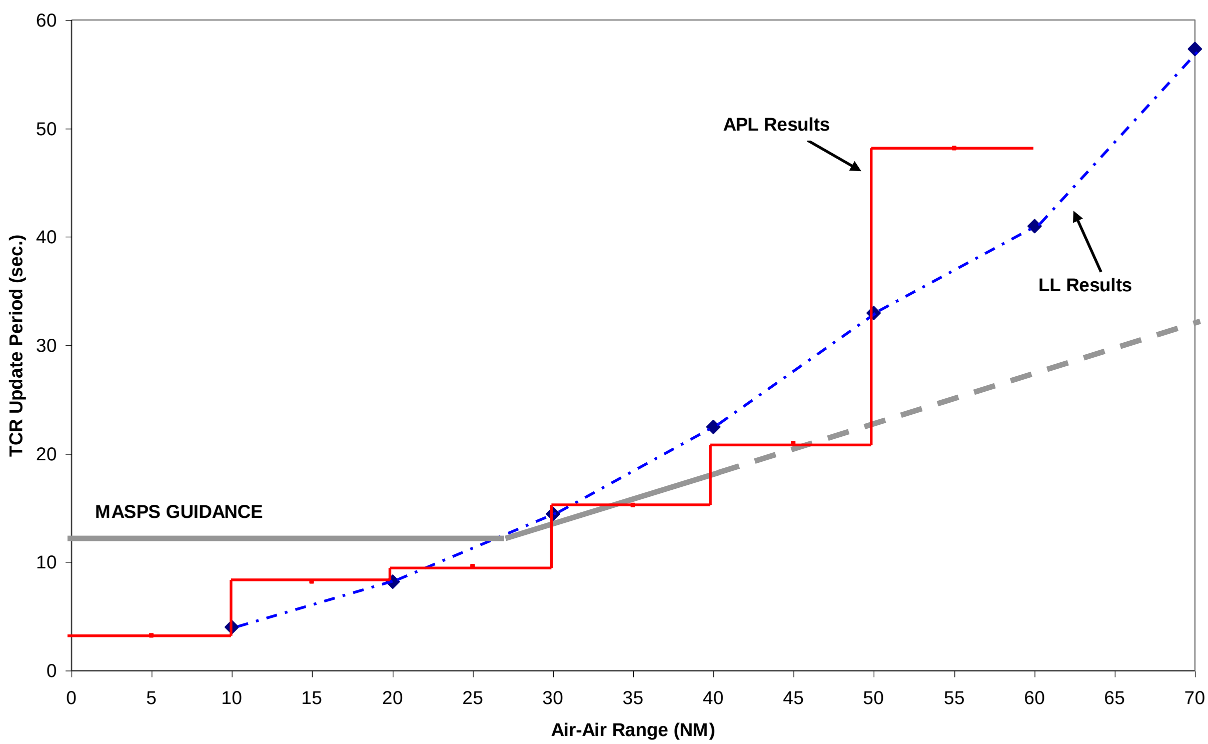
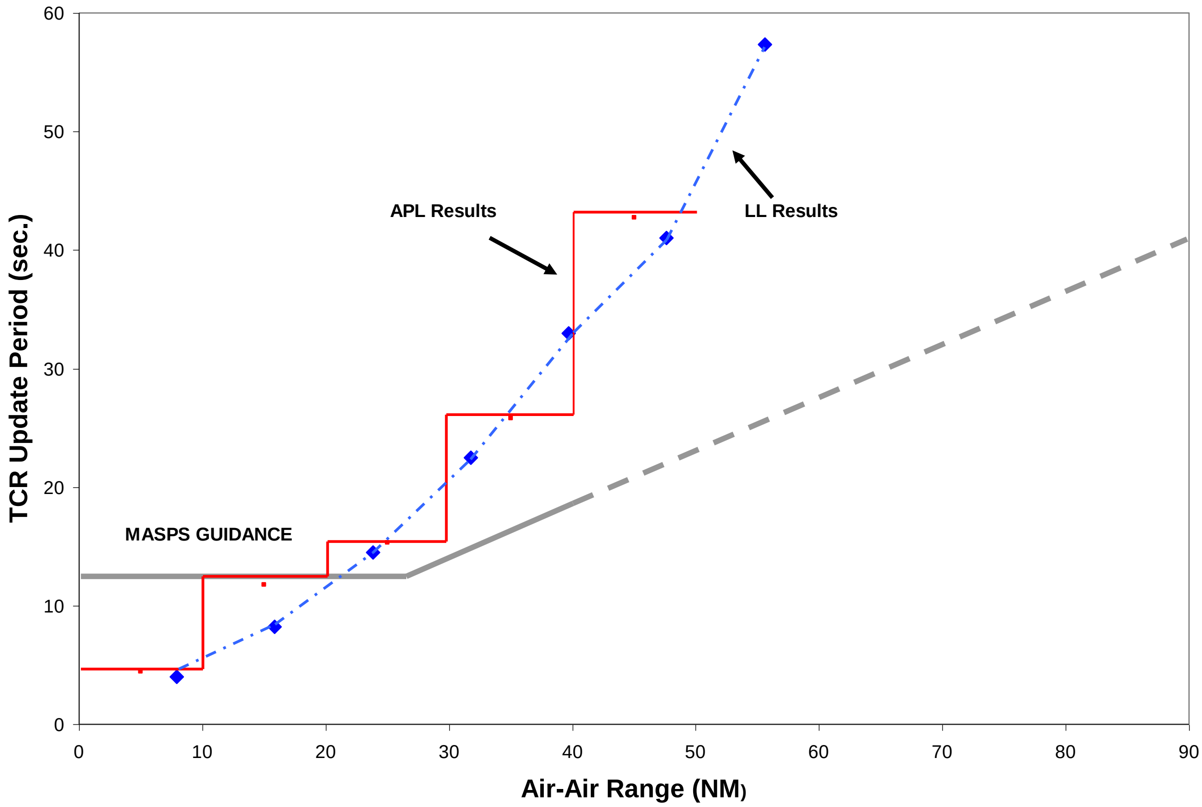


Figure O-4: Case 2 – LA2020-[24k] for A3 Tx -to- A3 Rx



<u>Figure O-5:</u> Case 2 – LA2020-[24k] for A2 Tx -to- A3 Rx

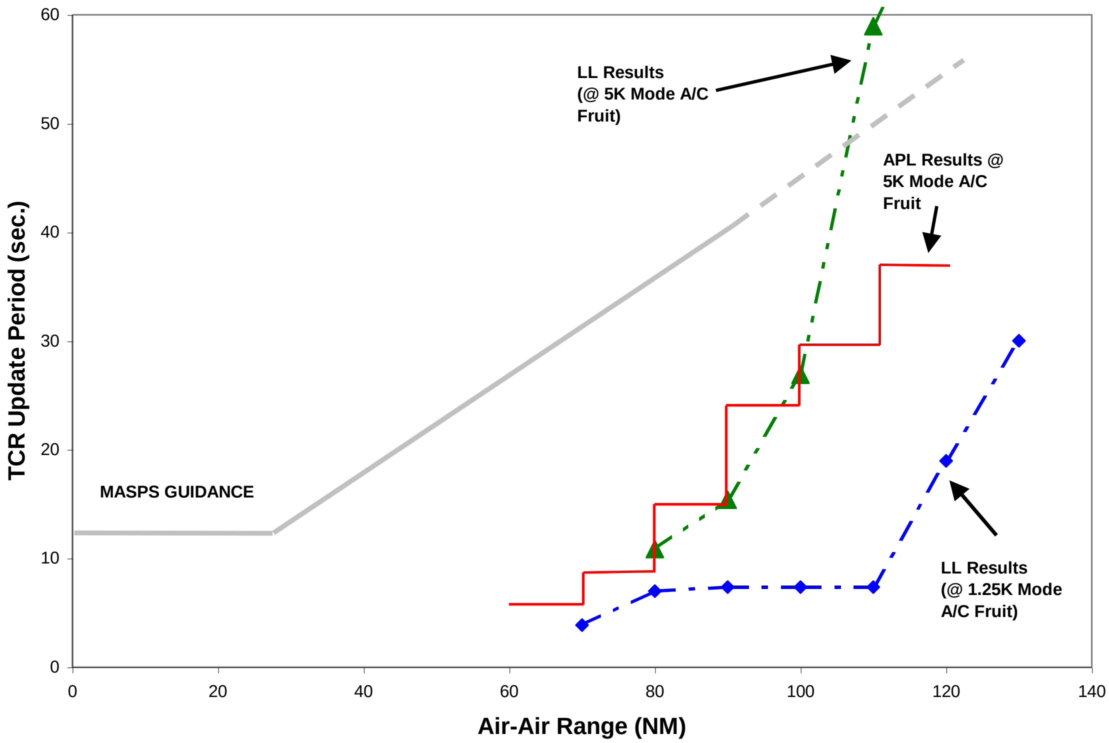


Figure O-6: **Case 2 – Low Density A3 Tx -to- A3 Rx**

Case 3 –

For **Case 3**, it is assumed that both a TC+0 Basic and a TC+0 Supplemental Messages would be broadcast at 0.4 messages per second. This would be the worst-case situation, in which the peak Extended Squitter transmission rate is limited to 6.2 squitters per second, where the aircraft is sending the full TC+0 information set and where the supplemental information could not be updated at a lower rate than the basic information. In order to support the ADS-B MASPS guidance for TC+0 Report updates at 95% probability, the nominal required per message reception probability is described by the formula: $0.95 = [1 - (1\text{-}P_{message})^N]^2$ or rewriting for calculating the necessary per squitter reception probability: $P_{message} = 1 - [1\text{-} (0.95)^{1/2}]^{1/N}$ where **N** is the number of transmissions within the required received update interval. The Table O-8 indicates the per message reception probability needed to satisfy the RTCA DO-242A guidance for the nominal air-to-air reporting of TC+0 information at ranges of 20, 40 and 90 NM.

Table O-8: **Case 3 – TC Message Reception Probability**

Air-Air Range	TC+0 Report Nominal Update Rate	"Required" Message Reception Probability
20 NM	12 Seconds	53.5%
40 NM	18 Seconds	40.0%
90 NM	41 Seconds	20.1%

In **Case 3**, the effective reporting rate for TC+0, in which both a Basic TC+0 Message and a Supplemental TC+0 Message is being broadcast, and the broadcast rate for each is 0.4 messages per second, the estimated TC+0 reporting rate is summarized in Table O-9 and Figure O-7, Figure O-8 and Figure O-9 for the LA2020 and the low traffic density scenarios for the case of Class A3 receiving systems.

Table O-9: Case 3 – TC Report Performance

TC+0 Report Update Rate	Estimated Air-Air Range for Low Density Scenario (A3 Tx -to- A3 Rx)		Estimated Air-Air Range LA2020 Scenario (A2 Tx -to- A3 Rx)		Estimated Air-Air Range LA2020 Scenario (A3 Tx -to- A3 Rx)	
	APL	LL	APL	LL	APL	LL
12 Sec.	80 NM	75 NM	10 NM	12 NM	10 NM	15 NM
18 Sec.	90 NM	110 NM	10 NM	17 NM	20 NM	22 NM
41 Sec.	110 NM	121 NM	30 NM	30 NM	40 NM	37 NM

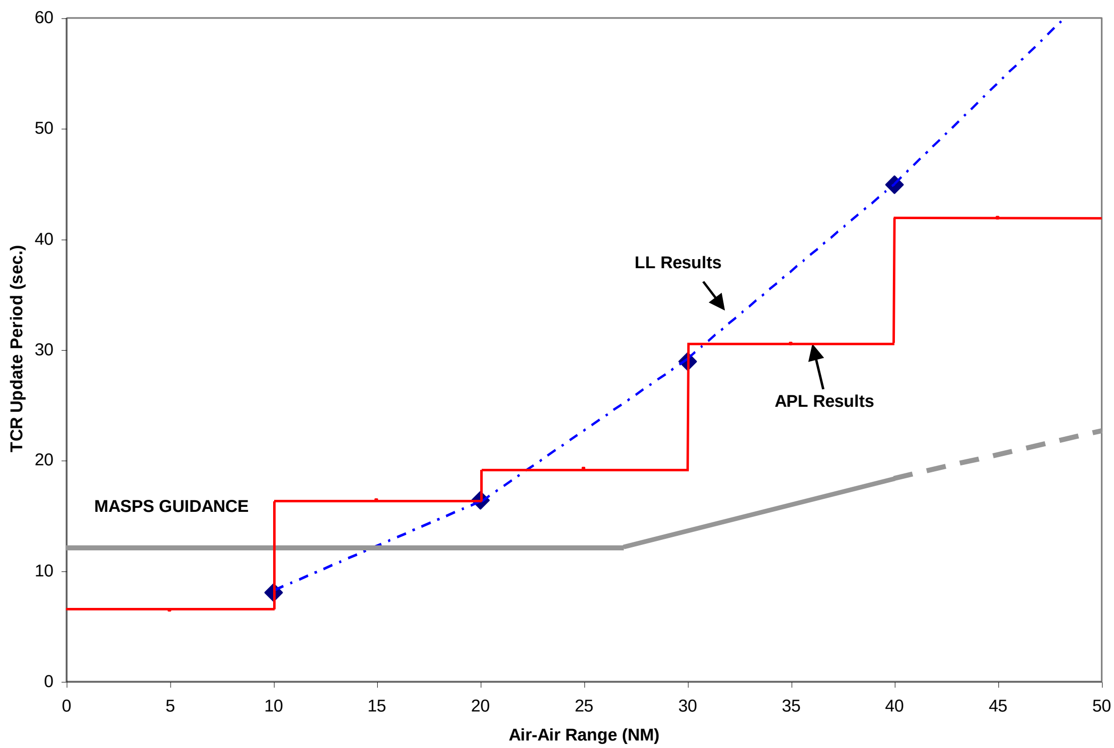
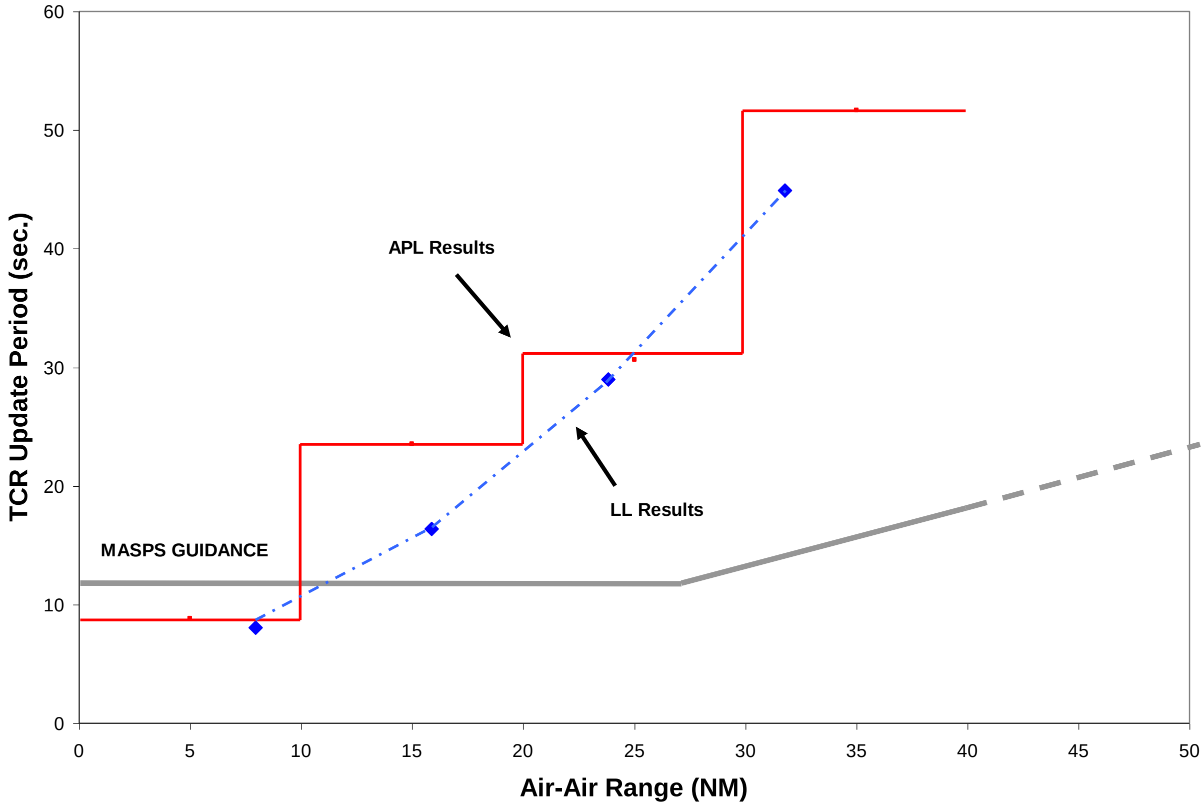


Figure O-7: Case 3 – LA2020-[24k] for A3 Tx -to- A3 Rx



<u>Figure O-8:</u> Case 3 – LA2020-[24k] for A2 Tx -to- A3 Rx

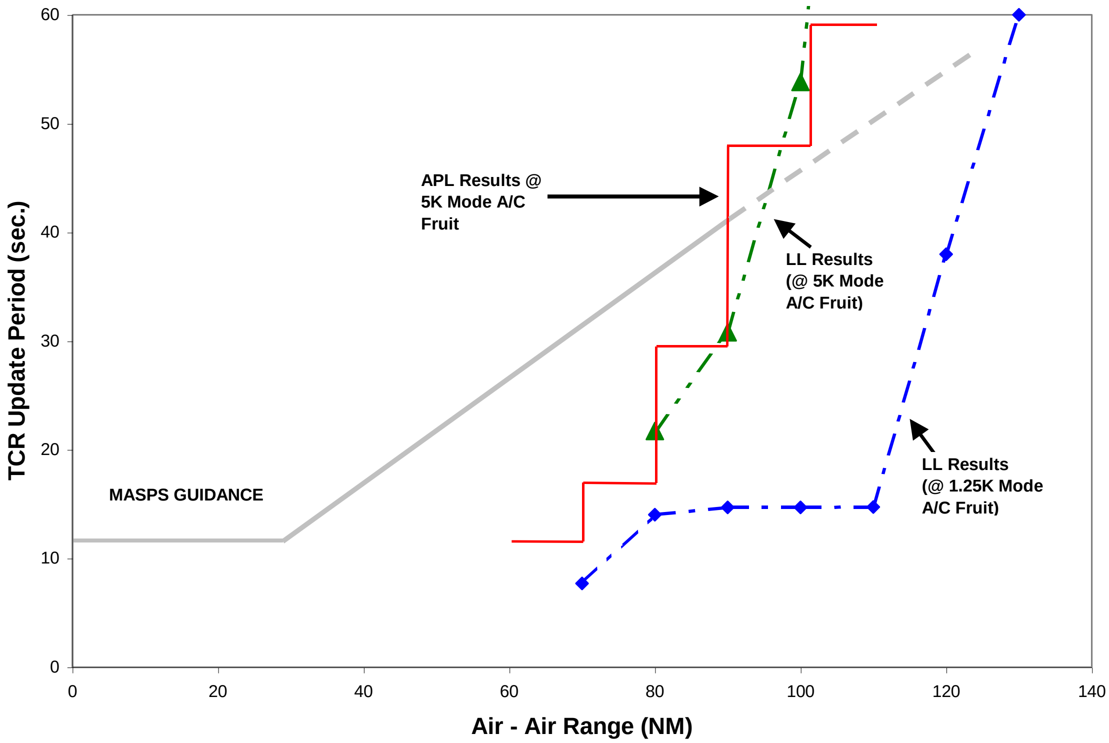


Figure O-9: **Case 3 – Low Density A3 Tx -to- A3 Rx**

O.5.2 TC+1 Performance Estimate

The broadcast of TC+1 information in support of an air-to-air application should only be considered on 1090 MHz if the allowed peak Extended Squitter rate is increased above the current RTCA MOPS and ICAO SARPs limit of 6.2 squitters per second. If the limit were increased to the order of 8 to 8.6 squitters per second then the performance for TC+1 reporting would be similar to that described above in §O.5.1 for **Case 1** and **Case 2**. However, in order to limit channel loading and in order to gain ICAO acceptance for an increase in the peak allowed squitter rate, the transmission of TC+1 Messages might need to be limited to operations above a fixed altitude threshold, such as only in high altitude en route airspace where airborne flight path de-confliction might be operationally authorized.

O.6 Other Factors and Issues

The performance estimates presented above in §O.5 address only the air-to-air reception of TC information. It is possible that the primary needs for TC information are not best served by the exclusive use of ADS-B as the delivery mechanism and/or are not best offered as an air-to-air service. For example, this could be the case with high density terminal environments where the responsibility for aircraft separation will remain the responsibility of the ATC controller and supported by the ground automation tools. For this case, addressed Mode S services may be a technically superior method for the ground ATC automation system to obtain the aircraft's intent information. Once the intent information is obtained by the ground ATC automation and used by the ground decision support tools, it may be appropriate to employ an addressed (or broadcast) ground-to-air communications service to provide airborne applications with the information they to achieve conflict free flight paths.

The air-to-ground performance for 1090 MHz Extended Squitter is substantially better than for the air-to-air case. This is a consequence of the use of substantially higher gain antennas at the ground stations and the ground station receivers are subjected to substantially lower levels of co-channel interference (i.e., fruit) as a result of Earth curvature and other line-of-sight obstructions. Also ground stations equipped with sector antennas are expected to achieve further improvements improved signal strength and reduced interference levels. Furthermore, the networking of multiple ground stations can provide a more robust service with higher effective update rates. The rate at which TC information is broadcast may need to be tailored to satisfy the most important of the operational needs. This could imply that the broadcast rate, and perhaps the information contents of TC Messages, be varied depending on the operational environment in which the aircraft is operating. A simple example would be to include an altitude dependency on the types of intent information being broadcast (e.g., TC+1 only broadcast above a fixed altitude).

O.7 Conclusions

The predicted performance for the reception of Trajectory Change information on 1090 MHz ADS-B is expected to well exceed the RTCA DO-242A, Appendix N, guidance on TC+0 Report update rates in low density environments where air-to-air ranges in excess of 100 NM are possible.

For the future LA2020 high density scenario the two simulation models employed for this assessment have produced similar results. Both sets of simulation results indicate that for Class A3 receivers receiving broadcasts from Class A3 transmitters it may be possible to satisfy the ADS-B MASPS guidance for TC+0 reporting at air-to-air ranges of approximately 40 to 50 NM if only TC Basic messages are being transmitted as described in Case 1. The performance for all three (3) Cases are summarized in Table O-10. At longer air-to-air ranges the effective update rate for TC+0 Reports would fall below the ADS-B MASPS guidance, but may prove usable for certain applications at ranges up to 60 NM where TC+0 updates rates of less than 40 seconds may be practical.

The performance for the reception of TC broadcasts from Class A2 systems being received by Class A3 systems is predicted to fall short of the ADS-B MASPS guidance in the case of the LA2020-[24k] scenario. For the case the ADS-B MASPS guidance on TC Report rates is predicted to be satisfied at air-to-air ranges to on the order of 20 to 30 NM if only TC Basic messages are being transmitted as described in Case 1. The performance for all three (3) Cases are summarized in Table O-10. However, beyond 30 NM the TC reporting rates may prove to be useful to certain applications at ranges of perhaps up to 40 NM where a TC Report update rate of less than 30 seconds may be possible.

However, in order to support such air-to-air ranges in the LA2020-[24k] scenario, and also to support the TC Report complete set of parameters defined in RTCA DO-242A, the peak transmission rate for Extended Squitters would need to be increased above the currently allowed maximum of 6.2 squitters per second. Support for TC+1 would also require an increase in the maximum rate allowed for Extended Squitter transmission.

For the case of an enroute aircraft directly over-flying LAX, the duration of time in which the air-to-air performance would be limited to the above ranges is perhaps 5 minutes or less. This is a consequence of the simulation models only considering the case in which the receiving aircraft is in the worst-case interference environment (i.e. near LAX). Experience from the 1090 MHz data collection conducted by the FAA in 1999 suggests that the 1090 MHz interference levels peak in the immediate vicinity of LAX and decrease away from this area.

It must be noted that the above analysis and conclusions are based on the air-to-air delivery of TC information in support of airborne based applications. In certain operational environments it may be more appropriate to focus on the air-to-ground delivery of TC information in support of ground-based ATC automation tools, rather than in support of airborne based applications. It is expected that for the air-to-ground delivery of TC Messages, the desired update rates could be achieved using the 1090 MHz ADS-B system within a future high density environment, such as represented by the LA2020 scenario.

Table O-10: Summary of TC Performance

	Case 1	**Case 2**	**Case 3**
Messages Sent	TC Basic	TC Basic & Supplemental	TC Basic & Supplemental
Extended Squitter Rate	6.2 ES / sec	7.0 ES / sec	6.2 ES / sec
TC Message Rate	0.8 msg / sec	0.8 msg / sec	0.4 msg / sec
A3-to-A3 with 24K Fruit	40 – 50 NM	27 – 40 NM	10 – 15 NM
A3-to-A3 with 5K Fruit	> 120 NM	> 120 NM	> 120 NM
A2-to-A3 with 24K Fruit	23 – 30 NM	20 – 22 NM	10 – 12 NM

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Appendix P

1090 MHz System Performance Simulation Results

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P 1090 MHz System Performance Simulation Results

P.1 Introduction

The air-to-air performance of 1090 MHz Extended Squitter (1090 ES) has been evaluated, as described in this Appendix. Two detailed evaluations were carried out using different techniques, although the air traffic scenarios evaluated were the same. The results from the two evaluations are relatively close and tend to support each other.

One evaluation was carried out by the Johns Hopkins University Applied Physics Laboratory (APL), and is described in Section P.2. The other evaluation was performed by MIT Lincoln Laboratory (LL), and is described in Section P.3. In both cases, the evaluations were applied to the Los Angeles Basin High Density (LA) scenario and the Low Density scenario defined in the ADS-B MASPS (RTCA DO-242A). This scenario is a future estimate derived by applying a growth factor of 1.5 to measured values. For the LA scenario, two cases were considered. In order to represent two potential worst-case interference environments, a nominal case with Mode A/C fruit rate of 24,000 per second, herein referenced as “LA-[24k],” and a more severe case of 30,000 Mode A/C fruit per second, herein referenced as “LA-[30k].” These scenarios are intended to represent the worst-case location for ADS-B reception within the LA Basin.

In other respects, very similar or identical models were used in the two evaluations.

- Aircraft Antenna Gain. The Technical Link Assessment Team (TLAT) model for aircraft antenna gain was used in both evaluations. This model, which is documented in Reference P-1, includes a function giving antenna gain vs. elevation angle, and also includes a statistical component, which has a defined distribution. The statistical distribution has a bell-shaped curve, skewed slightly toward negative values.
- Transmitter Power. The following statistical models were used in both evaluations. For class A0, power referred to the antenna is uniformly distributed between 48.5 and 51.5 dBm. For class A1 and class A2, power referred to the antenna input is uniformly distributed between 51 and 54 dBm. For class A3, power referred to the antenna is uniformly distributed between 53 and 56 dBm.
- Receiver MTL. Receiver MTL was treated as a constant in both evaluations, and was set to the worst-case value permitted by these MOPS.
- Fruit rates. Steps were taken to match the fruit rate models in the two evaluations. This was done by beginning with the APL model, running the part of the evaluation whose output is fruit rate and power distribution, shown separately for Mode A/C fruit and Mode S fruit. These curves were then used as inputs to the LL evaluation. The LL evaluation was performed under fruit conditions matched to the APL fruit rate results.

Analytical models and detailed simulations of data links operating in future scenarios are necessary to assess expected capabilities in stressed circumstances. Accurately modeling future capabilities for potential system designs in a fair way, however, is challenging. Since validation of simulation results in future environments is unrealistic, other means of verification such as the following are required. System characteristics represented in these simulations should agree with actual measurements on components of the proposed design, e.g., bench measurements on prototype equipment and calibrated flight test data should be used, when possible, for the receiver/decoder capabilities and as comparison with modeled link budgets. Similarly, suitable interference models help to support estimates of how these conditions may change in future scenarios. Credibility of any simulation results for future scenarios also requires that they be able to model current conditions and provide results that appropriately agree with measurements made under these conditions. Existing tools have been used as crosschecks where possible for the final detailed simulations and models. The differences between the results of the two evaluations are not surprising, given the above considerations and the different simulation approaches.

P.2 Performance Evaluation by APL

This section presents the evaluation of 1090 ES performance by APL, using the simulation models and techniques discussed below.

P.2.1 1090 Extended Squitter Detailed Simulation Features and Methodology

The APL 1090 ES detailed simulation is written in C and allows for horizontal, constant-velocity motion of the aircraft in the scenario. The simulation reads in the inputs specifying the particular case to be run (including a co-channel interference environment file produced by the Volpe/TASC simulator cited as Reference P-2), generates all of the ADS-B transmissions and additional interference for 300 seconds, calculates signal levels and times of arrival for each of these transmissions, and determines the corresponding message error rates for each ADS-B transmission at the individual times of arrival by all aircraft within line of sight of the victim receiver. This information is then written to an output file, one entry line for each ADS-B transmission, which is then analyzed by post-simulation software. A number of the real-world effects included in the simulation are discussed in Section P.2.1.1. Section P.2.1.2 will describe the post-simulation processing of the data.

P.2.1.1 1090 ES Detailed Simulation Features

This section describes some of the features of the 1090 ES detailed simulation:

- Propagation and other losses. The 1090 ES simulation calculates the free-space propagation loss for each transmission, using the range between transmitter and receiver at the time of transmission. There is also a receiver cable loss of 3 dB incorporated in the calculation. An optional transmit cable loss is also included in the simulation, but since the transmit powers have been defined at the antenna, the transmit cable loss has been set to zero for this study.

- Antenna gains. The antenna gain model used here was that specified in the TLAT Report [Reference P-1].

- Propagation delays. The propagation delay incurred by the signal in traversing the free space between transmitter and receiver has been included in the 1090 ES simulation.

- Co-channel interference. The 1090 ES transmissions co-exist with transmissions from other sources at the same frequency, such as Mode A/C, Mode S, and TCAS replies. These transmissions are responses to interrogations originating from ground interrogators and, in the case of TCAS, other aircraft. The ground interrogator environment is described in the TLAT report [Reference P-1]. All A2 and A3 aircraft are assumed to be equipped with TCAS, for a total of 40% of all aircraft in the LA- scenario. The cases evaluated had no loading of the channel due to Mode S air-ground data link. Several different estimates of the co-channel interference environment were examined for the high-density LA scenario:

- 24,000 Mode A/C, 2,500 Mode S at levels greater than –84 dBm
- 30,000 Mode A/C, 3,600 Mode S at levels greater than –84 dBm

For the low density scenario, a rate of 5,000 Mode A/C was used.

- Co-site interference. Co-site transmissions of 1090 ES messages, DME interrogations, Mode S interrogations and replies, whisper-shout interrogations, and Mode A/C replies are all modeled as interference in the 1090 ES simulation. All of these are treated as "self-interference," and it is assumed that no 1090 ES reception may occur during any of these co-site transmissions (including a 15 microsecond "ramp-down" period added to the end of each co-site transmission). (See RTCA DO-282 for more detailed explanation of the co-site interference environment.)

- Multiple interference sources. The arrivals of 1090 ES messages at the victim receiver is a random process, due to the random nature of the transmissions and the propagation delays. There may be a number of messages and other interfering signals (e.g., Mode A/C) overlapping one another, and these overlaps will be for variable amounts of time. This interference is accounted for in the multi-aircraft simulation. Multiple interferers are treated in the receiver performance model by combining their interference levels in a way consistent with bench test measurements. The simultaneous presence of 1090 ES interference, co-channel interference, and self-interference is treated in a detailed fashion by the model.

- Alternating transmissions. The model simulates the alternating transmission sequence between top and bottom antennas as specified for A1, A2, and A3 equipage. For A0 equipage, the model simulates transmission from a top antenna.

- Receiver diversity. For A1, A2, and A3 equipage, the model simulates receiver diversity by calculating the message error rate at both the top and bottom receive antennas and calculating the joint reception probability. For A0-equipped aircraft, reception is only permitted from a top antenna.

- Transmit power variability. The transmit power specified at the antenna of an aircraft is chosen from a uniform distribution given by the limits specified by the authors of these MOPS for the aircraft equipage. For this analysis the ranges used were:

  - A3: 53-56 dBm
  - A2/A1: 51-54 dBm
  - A0: 48.5-51.5 dBm

Note: *These ranges were selected as being representative of equipment expected to be produced and deployed. It should be noted, however, that these MOPS allow for larger ranges of transmit powers and include, for example, the possibility of an A3 transmit power as low as 51 dBm.*

- Receiver re-triggering. The 1090 ES simulation checks each individual ADS-B message arriving at the victim receiver for its message error rate. This procedure amounts to allowing for re-triggering in the receiver, i.e. the potential for the receiver to switch from receiving a message to a stronger message signal that arrives after the start of the reception of the first message.

- Receiver performance model. The receiver performance model used in the 1090 ES simulation is based on experimental data collected on 1090 receivers that were provided for that purpose. The measurement data for these receivers were modified by simulation results provided by MIT Lincoln Laboratories (LL) and the FAA William J. Hughes Technical Center (FAATC). These simulation results were designed to emulate the enhanced decoding techniques, which have been incorporated as performance requirements for 1090 ES equipment. The development of the receiver performance model is described in Section 2 of this Appendix. The assumed sensitivity of the receiver is different for the different equipage classes, -84 dBm for class A3 and -79 dBm for A2/A1 equipage. This represents the signal level at which 90% of the messages are received correctly in the absence of interference. This parameter was validated in the simulation by examination of the signal vs. message error rate in the absence of interference. However, because the MOPS requirement of 15% message success at –87 dBm for A3 equipage is a more severe constraint, the effective MTL required is around –85.5 dBm for A3 aircraft. This is the value that was used in this analysis. The A1 equipage class receiver does not require the enhanced decoding techniques, so a different receiver performance model was used to evaluate A1 performance.
- Message transmission frequency and content. Section 2.2.3 defines the types of messages, their content, and the frequency of messages transmitted for each category of aircraft equipage. This is modeled in detail by the 1090 ES simulation.

P.2.1.2 Calculation of the Performance Metrics

The result of the 1090 ES detailed simulation is a file containing time-ordered information about each ADS-B squitter transmitted by every aircraft within line-of-sight of the victim receiver during the 300-second duration of the simulation. The main elements of information for each individual squitter include squitter type (information content) and the probabilities of reception on each of the top and bottom receive antennas. Each squitter will have individual reception probabilities which depend not only on signal level at each receive antenna at that time, but also on the interference environment at each of the antennas during the arrival of the squitter.

For each transmitting aircraft in a range bin of width ten nautical miles, the time-ordered sequence of squitters is then examined, and, using Monte Carlo techniques and the reception probabilities at each of the antennas, it is determined which of that transmit aircraft's squitters are successfully decoded by the receiver during the 300-second interval. From these successes, the State Vector update times are determined by computing the time difference between arrivals of successive squitters containing either position or velocity information. These update times are then ordered, and the 95^{th} percentile value is then chosen. This value represents the 95^{th} percentile update time for that particular transmitting aircraft. This procedure is then followed for each transmitting aircraft, resulting in a 95^{th} percentile update time for each aircraft.

All of the 95^{th} percentile update times for all of the aircraft in each range bin are then ordered, and the 95^{th} percentile of these update times is selected for the 95-95 State Vector update time. Thus, 95% of the aircraft in each range bin will have a 95% State Vector update time that is better than the 95-95 value for that bin.

The same procedure is then followed for the messages supporting Target State (TS) Reports, to determine the 95-95 update time for that type of message. The results of this analysis are presented in Sections P.2.3.2 and P.2.4.2 below, and results and conclusions are presented in Section P.2.5.

P.2.2 Receiver Performance Model

P.2.2.1 Background

In order to develop a receiver performance model for 1090 Extended Squitter (ES) to be used for the Technical Link Assessment Team (TLAT) ADS-B data link evaluation, bench test measurements of the Message Error Rate (MER) receive performance were made on an available 1090 ES receiver, which included a number of features of enhanced decoding. Development of this receiver performance model is described in the TLAT Report Appendix I. Subsequent to publication of the TLAT Report in April, 2001, the results of these measurements, compared with flight test measurements, led to the judgment that this receiver implemented a multi-sample technique that was not as effective at decoding 1090 ES messages as the multi-sampling technique incorporated in these MOPS. Thus, although some features of enhanced decoding were implemented in the tested receiver, it was felt that better performance could be achieved through modification of the decoding processing. For A2 and A3 category aircraft, these MOPS require performance equivalent to that achieved by the multi-sample techniques. Therefore, the receiver performance model was adapted to reflect those requirements.

P.2.2.2 Modifications to the Receiver Performance Model

The FAATC and LL developed and implemented simulations to predict 1090 ES receiver performance using enhanced decoding techniques, including multi-sampling. Several cases of Mode A/C interference were investigated, which led to detailed results for these cases being available for comparison with the predictions of the receiver performance model. The model was adjusted to account for these cases, resulting in a “modified receiver performance model.”

This modified receiver performance model was discovered to produce optimistic predictions in high-density environments, when compared with the overall results of the FAATC and LL predictions in these environments. It is not surprising that the results, which were based on a very small sample of the interference space, should differ from what is produced when extrapolated to and averaged over the entire high-density interference space. It was decided that it is more important to reflect the overall effects of the entire interference environment than to exactly replicate the few individual cases upon which the revised model was based.

The methodology adopted for this second modification of the receiver performance model was to “map” the model results to be consistent with the simulation results of the FAATC or LL, as appropriate. FAATC results were achieved by feeding video signals into a 1090 ES receiver front end and performing non-real-time software processing to determine message reception in a simulated high-density Mode A/C environment. The results were presented as the total message success probability as a function of the received desired signal level for the total Mode A/C interference environment. Individual cases were not identified, so a message success probability for a given signal level represents the averaging done over many different individual interference situations which characterize the entire interference environment.

For the A2 receiver, LL results were achieved by software simulation of signals and high-density interference (including phase and frequency fluctuations) and performing pulse-by-pulse non-real-time analysis to determine message reception. Again, as for the A3 results from the FAATC, the A2 results from LL (see Figure P-19) were presented as the total message success probability as a function of the received desired signal level for the total interference environment.

When compared to the results from the FAATC and LL simulations, which sampled the entire interference environment, the receiver performance model was found to be overly optimistic in its predictions of performance. In order to compensate for this bias, the receiver performance model was "mapped" separately to conform to the results of each of the two simulations, as illustrated for an A3 receiver in a 30,000 Mode A/C fruit environment shown in Figure P-1 below. This mapping was done separately to adjust the receiver performance model to the various interference levels and receiver sensitivities.

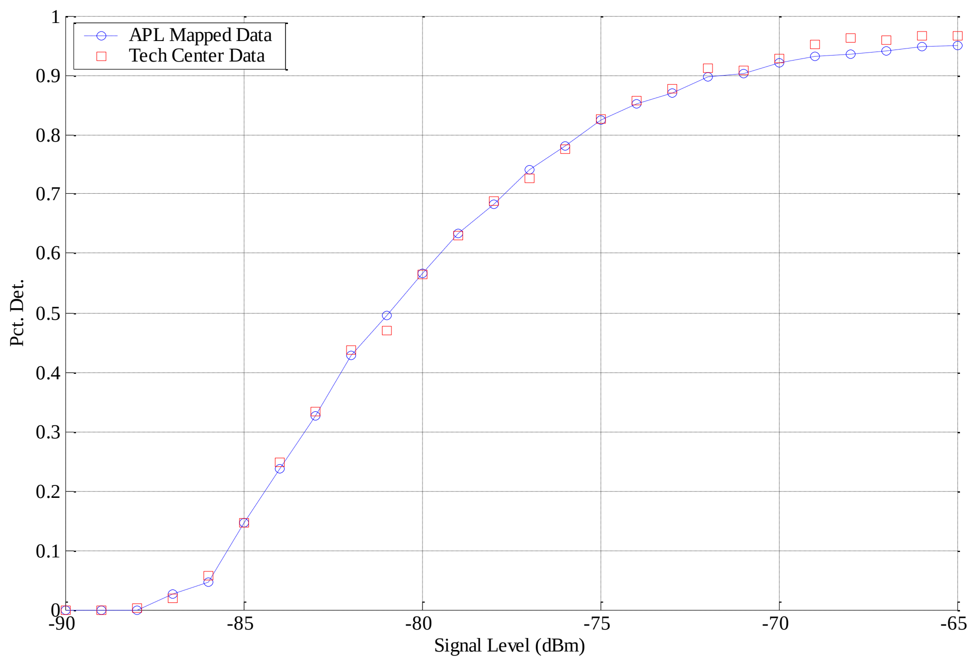


Figure P-1: Comparison of "Mapped" APL Receiver Performance Model Prediction with FAATC Simulation Results

Each of the various mappings (corresponding to scenario, fruit level, and multi-sampling type) was used for the appropriate receiver case. For example, to evaluate Class A3 performance in the 24,000 Mode A/C LA scenario, the receiver performance model was mapped to match the FAATC results for the 10 MHz sampling rate enhanced decoder for this fruit rate.

P.2.3 Los Angeles Basin High Density (LA)

P.2.3.1 LA Scenario Description

This scenario is based on the LA Basin 1999 maximum estimate. It is assumed that air traffic in this area would increase by a few percent each year until it would be 50 % higher than in 1999. The distribution of aircraft in the scenario is based on approximations of measured altitude and range density distributions.

The following assumptions are made for the airborne and ground aircraft, and ground vehicles for the LA Basin scenario:

- The density of airborne aircraft is taken to be:
  - Constant in range from the center of the area out to 225 nautical miles (5.25 aircraft/NM), (i.e., the inner circle of radius one NM would contain approximately five aircraft, as would the ring from 224 to 225 NM) and
  - Constant in area from 225 NM to 400 NM (.00375 aircraft/NM^2).
- There are assumed to be a fixed number of aircraft on the ground (within a circle of radius 5 NM at each airport), divided among LAX, San Diego, Long Beach, and five other small airports, totaling 225 aircraft. Half of the aircraft at each airport were assumed to be moving at 15 knots, while the other half were stationary. In addition, a total of 50 ground vehicles are distributed at these airports as well.
- The altitude distribution of the airborne aircraft is assumed to be exponential, with a mean altitude of 5500 feet. This distribution is assumed to apply over the entire area.
- The airborne aircraft are assumed to have the following average velocities, determined by their altitude. The aircraft velocities for aircraft below 25000 feet are uniformly distributed over a band of average velocity +/- 30 percent.
  - 0-3,000 feet altitude 130 knots
  - 3,000-10,000 ft 200 knots
  - 10,000-25,000 ft 300 knots
  - 25,000-up 450 knots
- The aircraft are all assumed to be moving in random directions.
- In the LA scenario, ADS-B equipage Class A0 aircraft are assumed to fly below 18,000 feet. All other aircraft are assumed to be capable of flying at any altitude. The aircraft in the LA scenario are assumed to be in the following proportions:
  - A3 30%
  - A2 10%
  - A1 40%
  - A0 20%

The scenario for the LA high density case contains a total of 2694 aircraft: 1180 within the core area of 225 NM, 1289 between 225-400 NM, and 225 on the ground. This represents a scaling of the estimated maximum 1999 LA Basin levels upward by 50 percent. Of these aircraft, 471 lie within 60 NM of the center. (This includes aircraft on the ground.) Around ten percent of the total number of aircraft are above 10,000 ft in altitude, and more than half of the aircraft are located in the outer (non-core) area of the scenario.

An attempt was made to at least partially account for the expected lower aircraft density over the ocean. In the third quadrant (between 180 degrees and 270 degrees), for distances greater than 100 NM from the center of the scenario, the density of aircraft is reduced to 25 % of the nominal value used. The other 75% of aircraft that would have been placed in this area are distributed uniformly among the other three quadrants at the same range from the center. This results in relative densities of 1:5 between the third quadrant and the others.

P.2.3.2 LA Results and Analysis

The ADS-B MASPS requirements for ADS-B air-to-air surveillance range and report update interval are used to assess how each ADS-B link performs in relation to the free flight operational enhancements identified by the RTCA Safe Flight 21 Steering Committee. These requirements specify the minimum range for acquisition of the State Vector, Mode Status and Target State Reports where applicable, as well as the maximum update periods allowed for this information (See ADS-B MASPS, RTCA DO-242A). These air/air criteria specify ranges, use of short-term intent information (TS Reports), and update times. The projected Trajectory Change (TC) long-term intent reporting capabilities of 1090 ES are described in Appendix O of these MOPS.

Results are presented as a series of plots of 95% update times as a function of range for State Vector updates and intent updates, where applicable. The 95% time means that at the range specified, 95% of aircraft pairs will achieve a 95% update rate at least equal to that shown. The 95-95 metric was calculated by placing the aircraft in range bins of ten (10) NM width and plotted in the form of histograms. The ADS-B MASPS requirements are also included on the plots for reference. Since the transmit power and receiver configuration are defined for each aircraft equipage class, performance is shown separately for each combination of transmit-receive pair types for A2 and A3 class equipment. Results are shown in Figure P-2 through Figure P-13 and conclusions are presented below. Note that, due to unavailability of receiver performance results for A2 in the 30,000/second Mode A/C environment, results for A2 are presented only for the 24,000/second case. The ADS-B MASPS requirements for State Vector, and projected requirements for TS Report updates are also shown on the plots. Performance in compliance with MASPS requirements is indicated by results that are below the MASPS line.

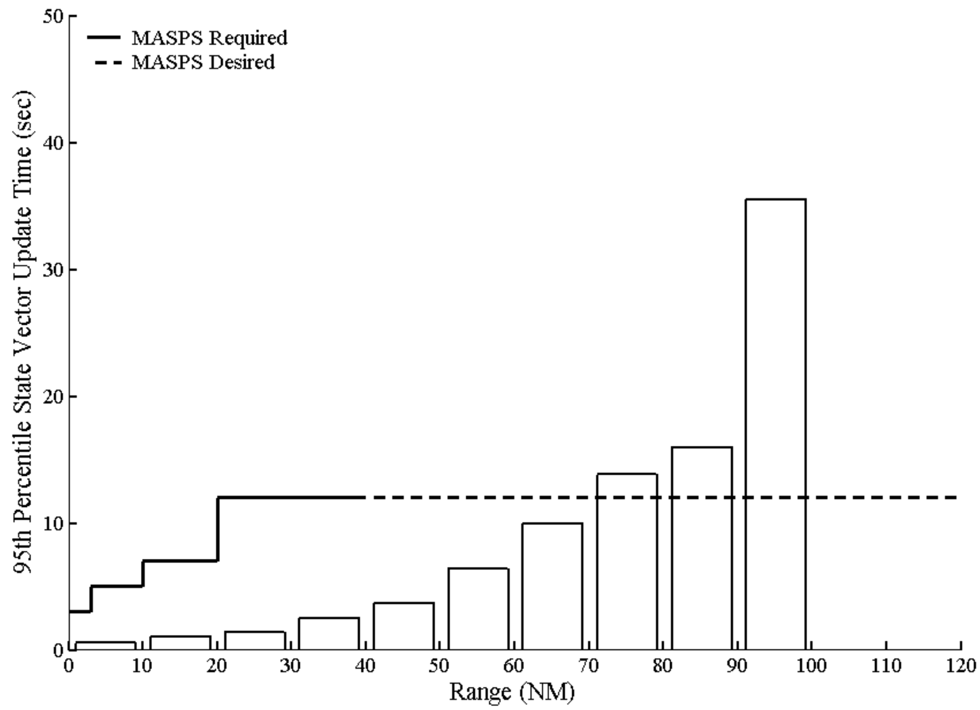


Figure P-2: 95-95 State Vector Update Rate for A3-to-A3 Air-to-Air Reception in LA-[24k]

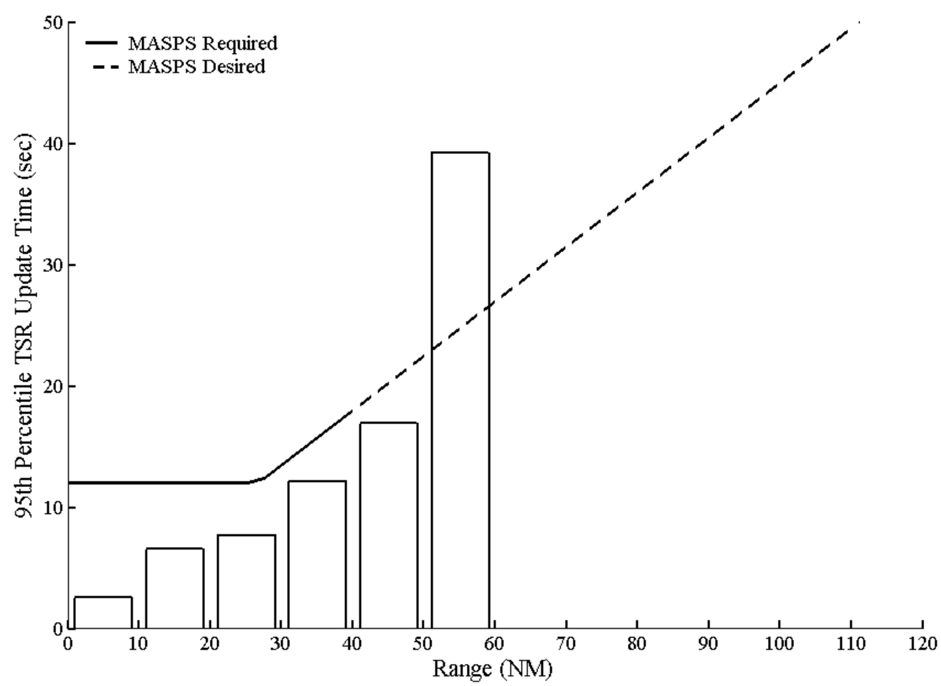


Figure P-3: 95-95 TSR Update Rate for A3-to-A3 Air-to-Air Reception in LA-[24k]

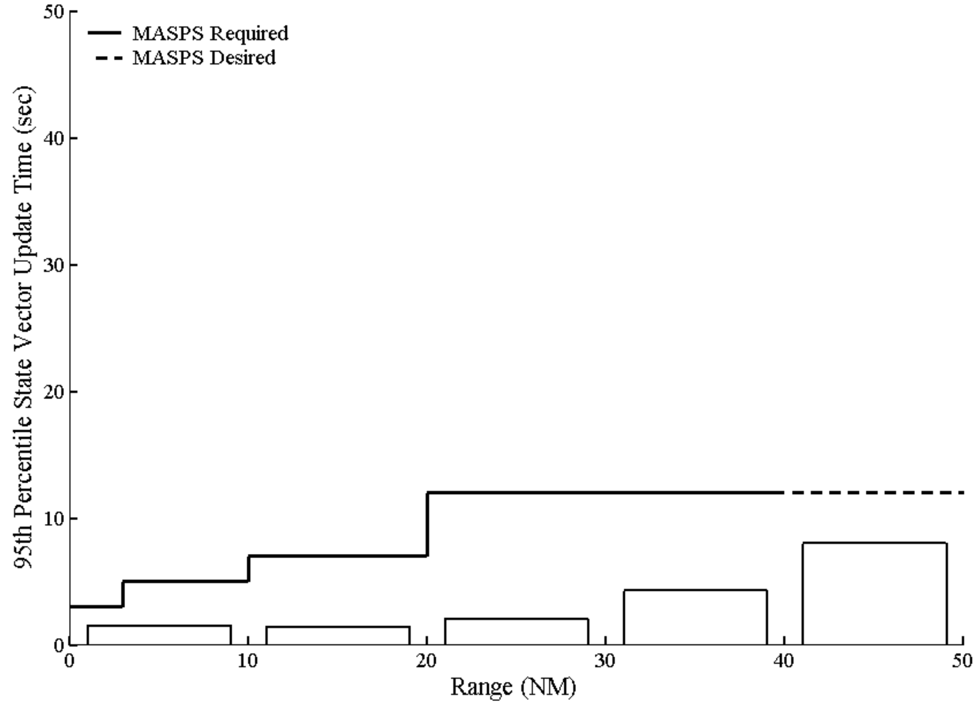


Figure P-4: **95-95 State Vector Update Rate for A2-to-A3 Air-to-Air Reception in LA-[24k]**

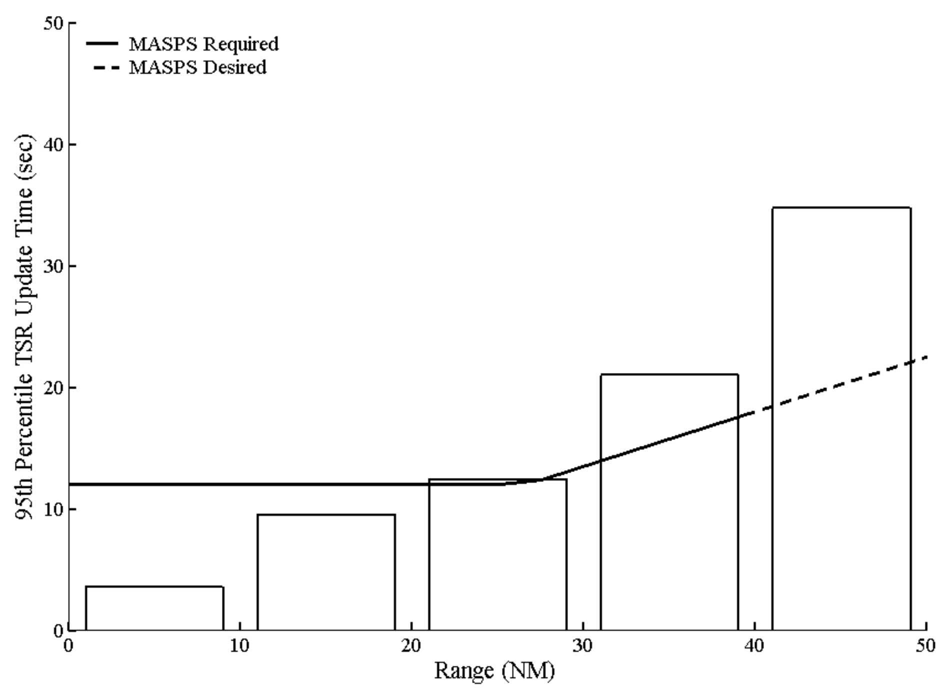


Figure P-5: **95-95 TSR Rate for A2-to-A3 Air-to-Air Reception in LA-[24k]**

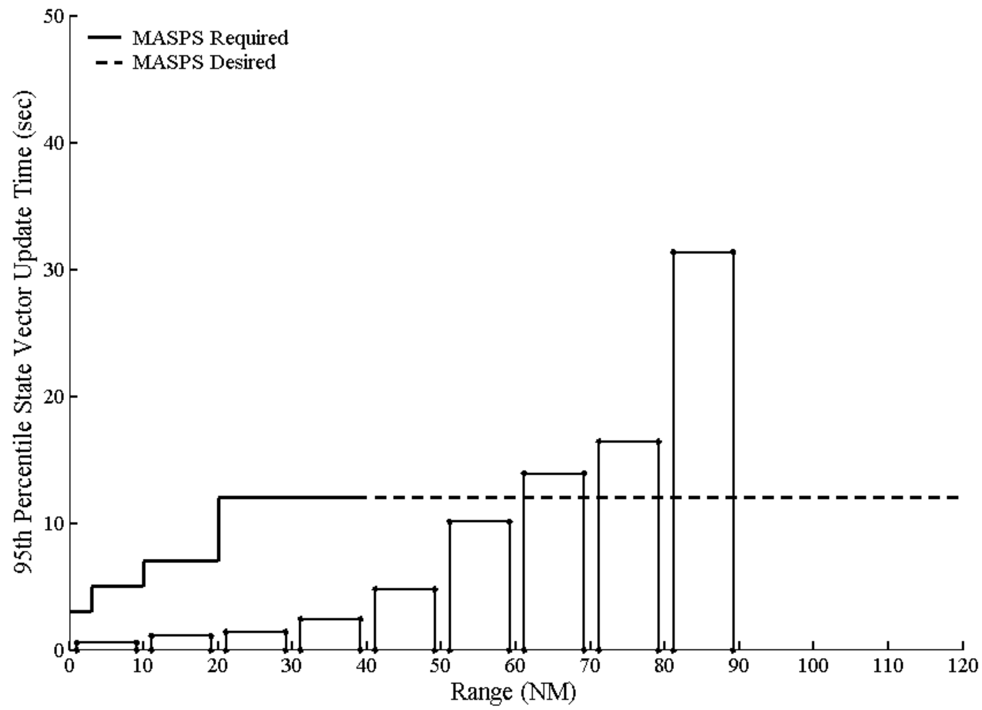


Figure P-6: **95-95 State Vector Update Rate for A3-to-A3 Air-to-Air Reception in LA-[30k]**

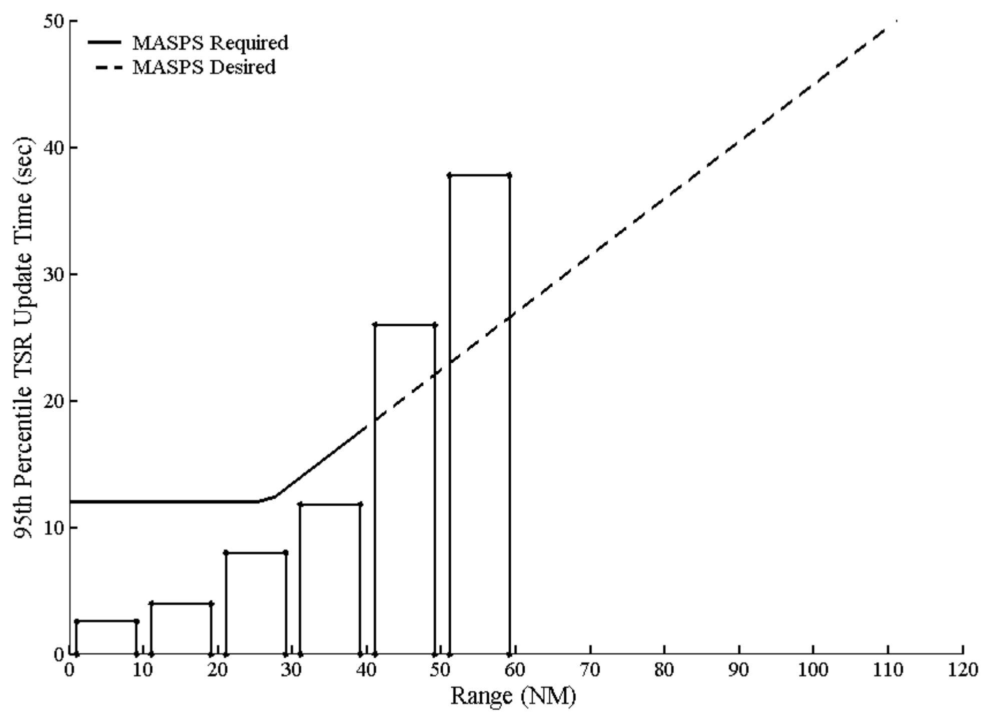


Figure P-7: **95-95 TSR Update Rate for A3-to-A3 Air-to-Air Reception in LA-[30k]**

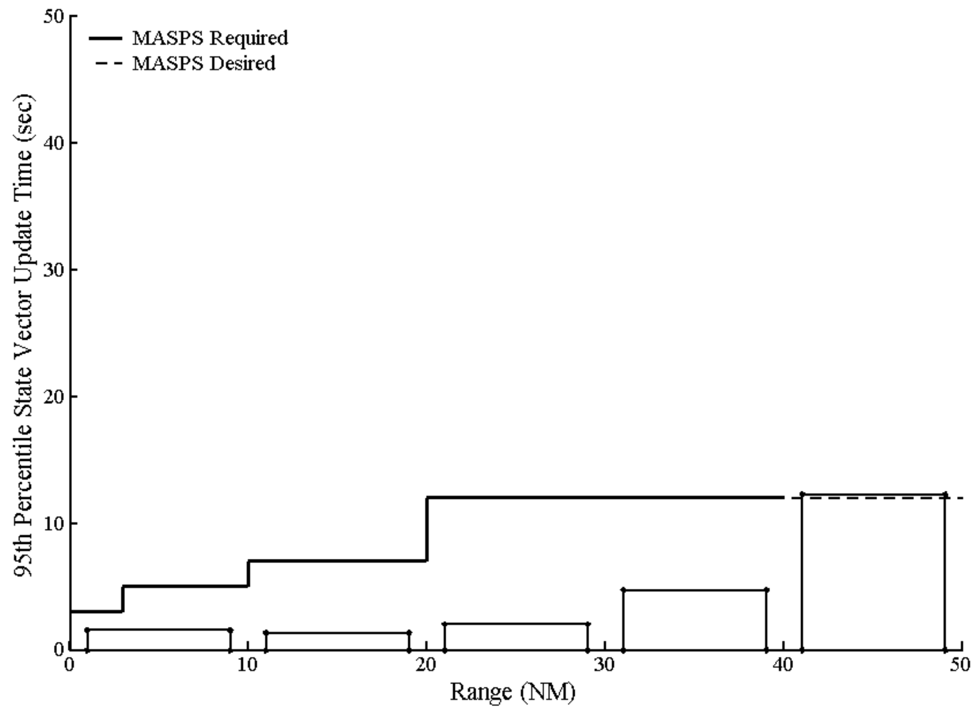


Figure P-8: 95-95 State Vector Update Rate for A2-to-A3 Air-to-Air Reception in LA-[30k]

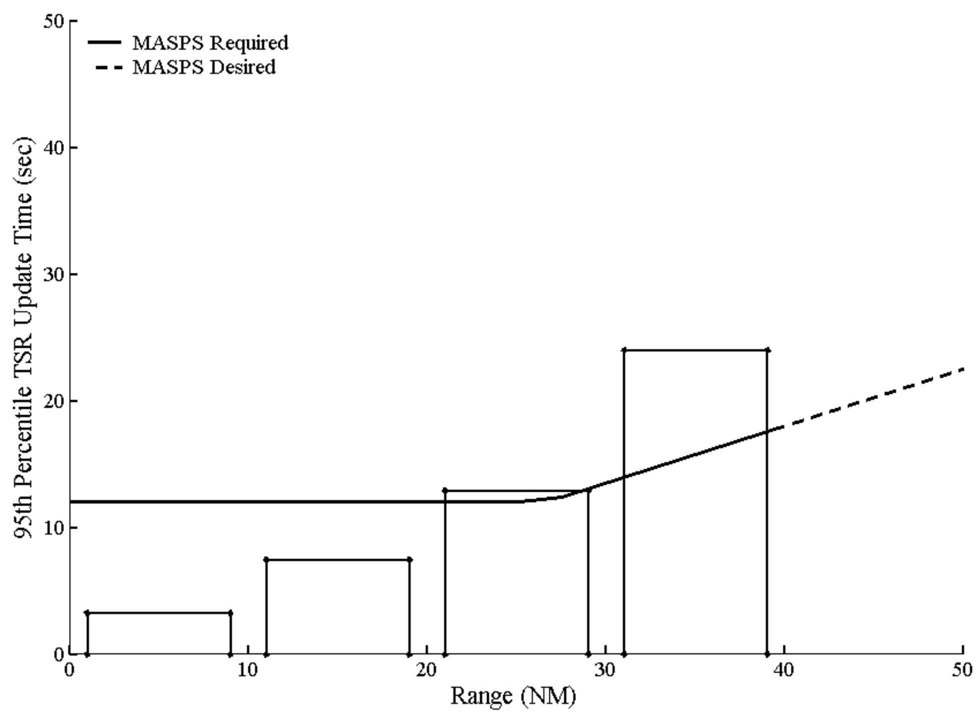


Figure P-9: 95-95 TSR Update Rate for A2-to-A3 Air-to-Air Reception in LA-[30k]

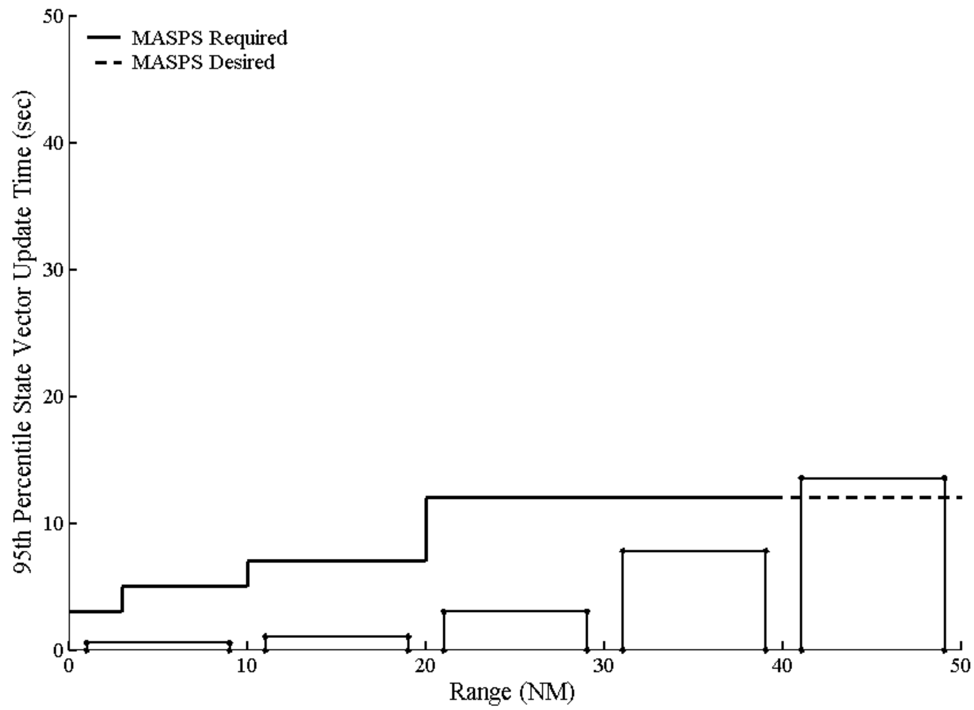


Figure P-10: **95-95 State Vector Update Rate for A3-to-A2 Air-to-Air Reception in LA-[24k]**

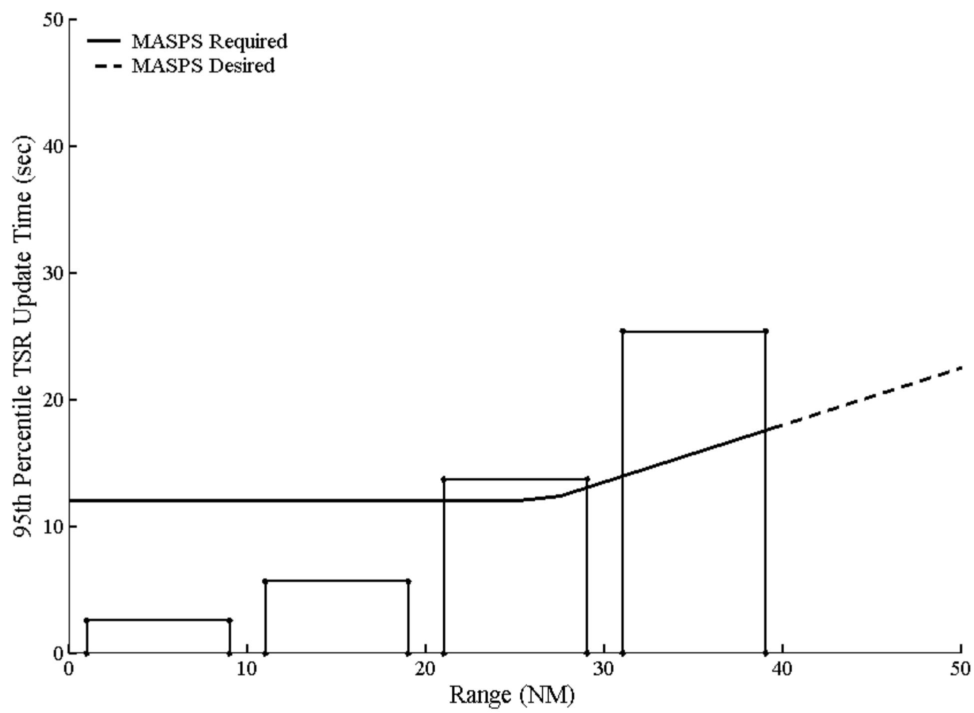


Figure P-11: **95-95 TSR Rate for A3-to-A2 Air-to-Air Reception in LA-[24k]**

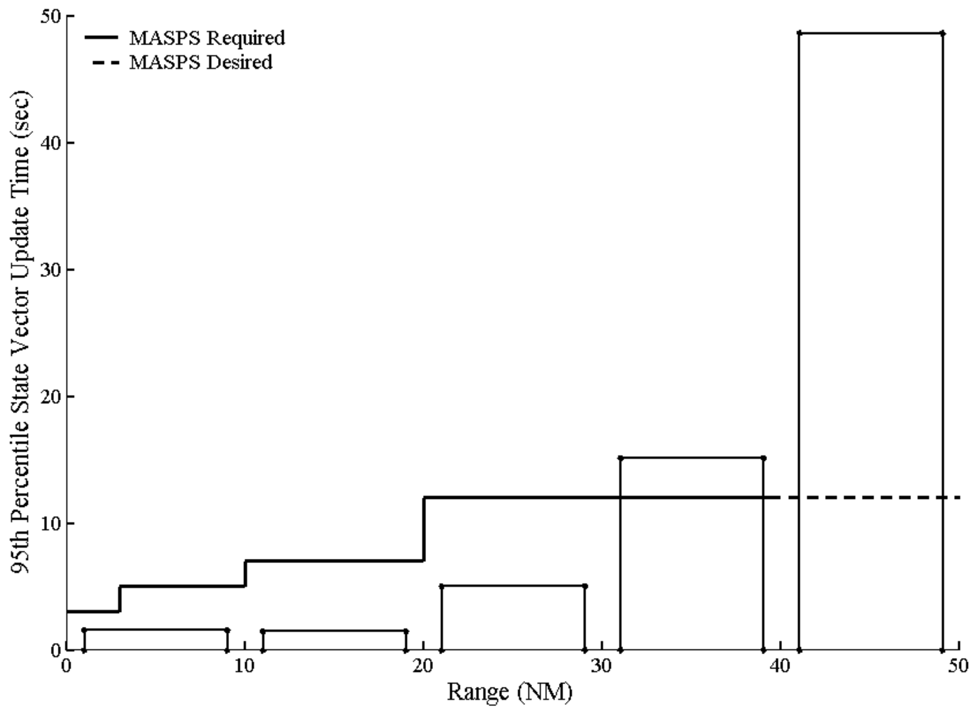


Figure P-12: **95-95 State Vector Update Rate for A2-to-A2 Air-to-Air Reception in LA-[24k]**

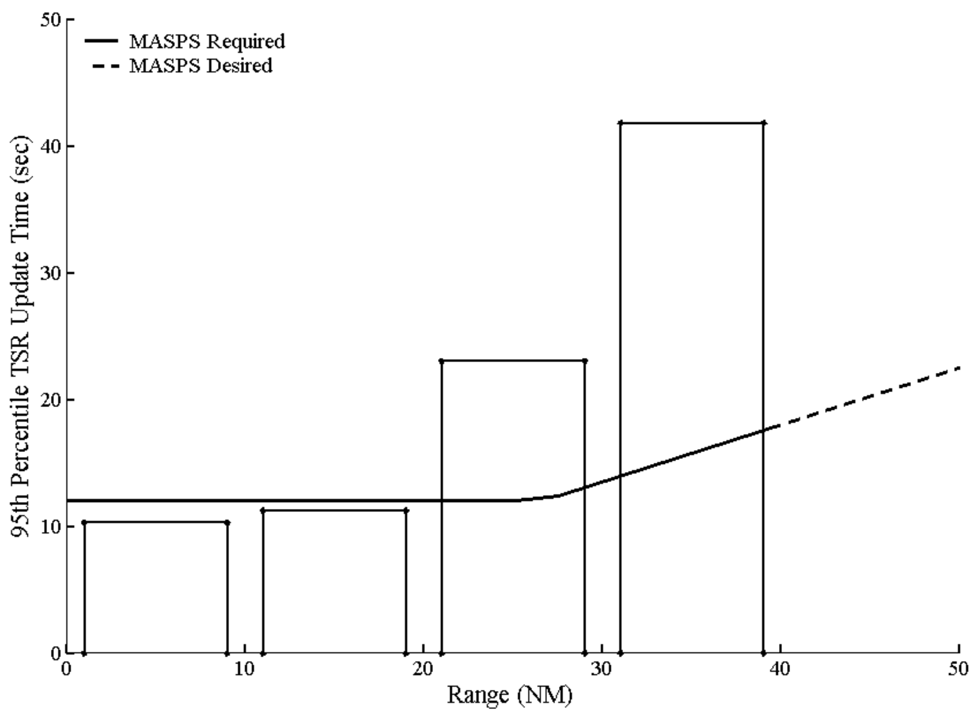


Figure P-13: **95-95 TSR Update Rate for A2-to-A2 Air-to-Air Reception in LA-[24k]**

The results for LA shown in Figure P-2 through Figure P-13 are summarized in Table P-1. The values in the table are determined from the histograms by looking at the bars in the ten-mile bins and using the upper range for the last bin that is under the requirement line. For example, in Figure P-13 above, the ten-mile bar from 10-20 NM is the last bin under the requirement line, so the range for the 95-95 metric for A2-to-A2 TSR updates is 20 NM.

Table P-1: APL Air-to-Air 1090 ES Performance Relative to ADS-B MASPS

Transmitter	Receiver	Mode A/C	Range to Which MASPS Performance is Met	
			State Vector	Target State
A3	**A3**	24,000	70 NM	50 NM
A2	**A3**	24,000	50 NM	20 NM
A3	**A3**	30,000	60 NM	40 NM
A2	**A3**	30,000	40 NM	20 NM
A3	**A2**	24,000	40 NM	20 NM
A2	**A2**	24,000	30 NM	20 NM

Note: *For the LA scenario, two cases were considered, in order to represent two potential worst-case interference environments, a nominal case with Mode A/C fruit rate of 24,000 per second, herein referenced as "LA-[24k]," and a more severe case of 30,000 Mode A/C fruit per second, herein referenced as "LA-[30k]."*

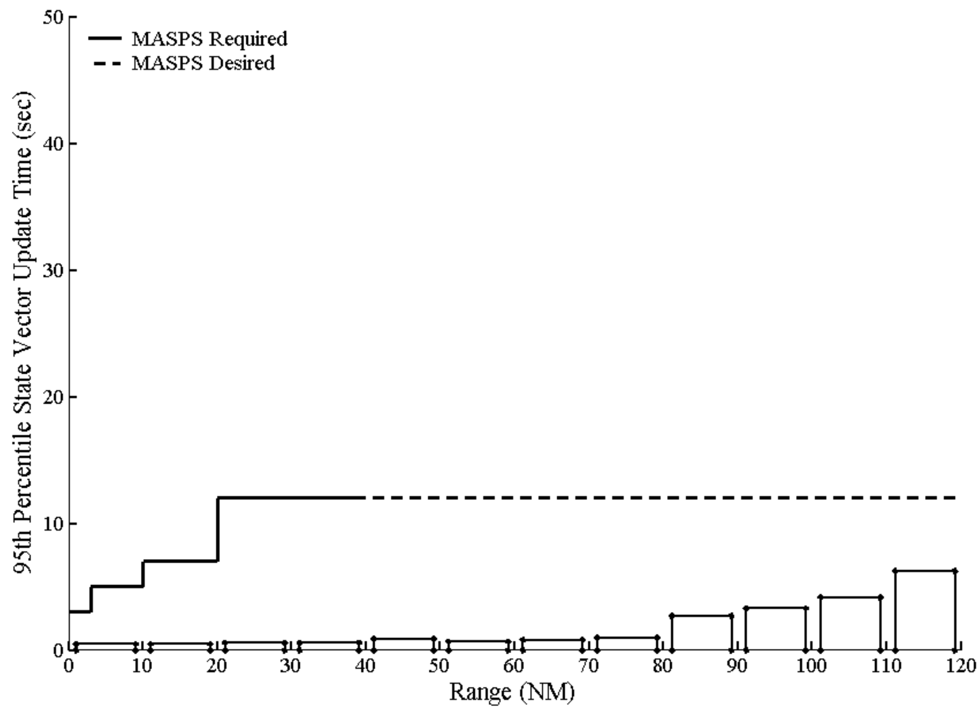
P.2.4 Low Density Scenario

P.2.4.1 Low Density Scenario Description

In addition to the high-density LA scenario described above, a scenario was also run to represent low-density traffic levels. This scenario, for simplicity, was developed by scaling the current LA Basin distributions downward by a factor of five, amounting to 360 total aircraft. These aircraft are uniformly distributed in the horizontal plane within a circle of 400 nautical miles. In the vertical direction, they are distributed uniformly between 25,000 feet and 37,000 feet. The velocities are all set to 450 knots and are randomly distributed in azimuth. All of the aircraft are assumed to be A3 equipped.

P.2.4.2 Low Density Results and Analysis

Results of the simulation runs for the low-density scenario are shown in Figure P-14 and Figure P-15, and conclusions are presented below. The ADS-B MASPS requirements for State Vector and TSR updates are shown as black lines on the plots. The ADS-B MASPS specify that the maximum ranges for air-air update rates required for A3 to 90 NM (120 NM desired), while the Eurocontrol criteria extend to 150 NM for A3. Performance in compliance with MASPS requirements is indicated by results that are below the black line.



<u>Figure P-14:</u> 95-95 State Vector Update Rate for A3-to-A3 Air-to-Air Reception in 5,000 Mode A/C per Second in the Low Density Scenario

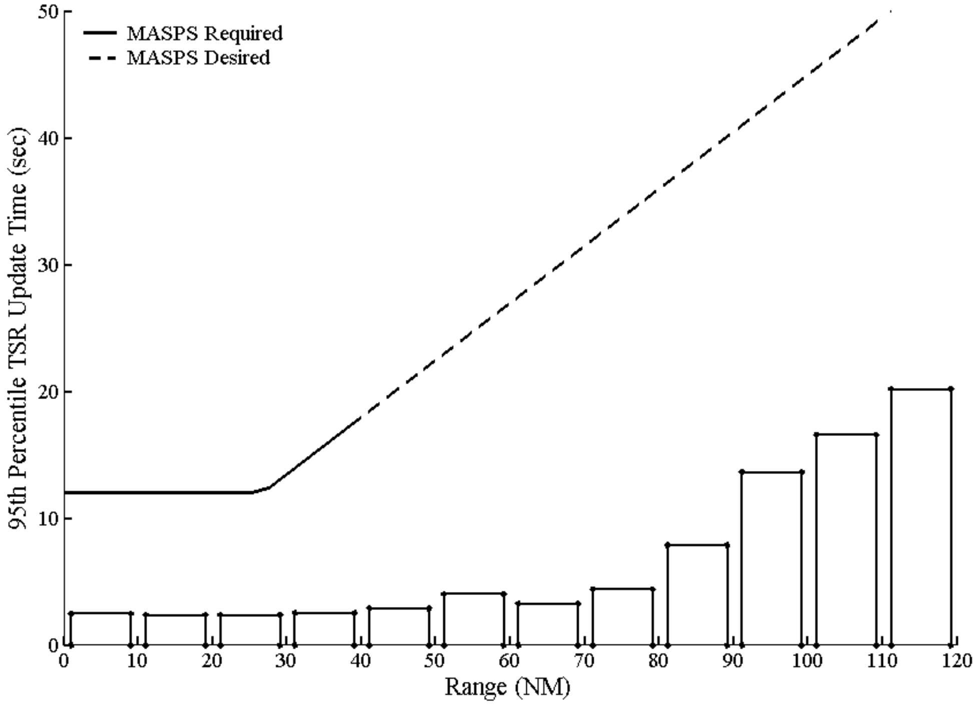


Figure P-15: 95-95 TSR Update Rate for A3-to-A3 Air-to-Air Reception in 5,000 Mode A/C per Second in the Low Density Scenario

The results for the low-density scenario may be summarized as follows:

- ADS-B MASPS air-air requirements and desired criteria are met for State Vector and TS Report updates at all ranges specified by the ADS-B MASPS for the low density scenario.

P.2.5 Results and Conclusions

This section summarizes the results of the APL simulation studies and states conclusions that may be drawn about expected 1090 ES performance in the scenarios considered. This summary will be presented in Section P.2.5.2. Section P.2.5.1 will first point out a number of considerations that should be taken into account when interpreting the results.

P.2.5.1 Considerations

The following considerations should be noted when interpreting the results of this analysis:

- The transmit power distribution for A3 transmitters, which was used for this analysis, was uniform from 53-56 dBm. These MOPS allow for A3 transmitters to extend as low as 51 dBm. This corresponds more closely to the transmit power distribution assumed for A2 class aircraft in this analysis; therefore, for a class A3 aircraft with a transmit power near the lower limit of the allowed range, it would be expected that performance would be given by A2 transmit results, rather than A3.

- The receiver performance model that was used for this analysis was based on non-real-time simulation results provided by the FAATC and MIT Lincoln Laboratory. Several manufacturer representatives have indicated that they felt that performance equivalent to that required by these MOPS was achievable. Still, there has been no testing of performance on MOPS-compliant equipment, and until this is done the receiver performance model has not been validated and remains hypothetical. In addition, the receiver performance model thus derived was designed to match the average performance predicted by the simulation results discussed above. This was necessary due to time and resources constraints and may add some additional uncertainty to the results.

- The results of this study should not be directly compared with any analysis not described in this Appendix, without taking into account differences in assumptions and analysis techniques. For example, the 1090 ES analysis in the TLAT report [Reference P-1] assumed different transmit power distributions, receiver decode performance, and Mode A/C interference levels, so it is not surprising that the results of that study differ from those reported here.

- Finally, in evaluating expected performance through the use of simulations, it is important to be aware of the inherent uncertainties in results due to the indeterminate nature of the assumptions, as well as the uncertainties in the modeling process itself. This is true for performance predictions resulting from any type of simulation technique. For example, in this analysis it was assumed that the number of aircraft in the LA Basin would increase by 50%, that most aircraft would be Mode S equipped, that a number of TCAS improvements would be universally deployed, and that the A3 transmit power would be as described above. These assumptions all include associated uncertainty; modifying any of the assumptions could result in a change in predicted performance.

P.2.5.2 Summary

Keeping in mind the conditions described in the previous section, the performance of 1090 Extended Squitter in the two scenarios examined may be summarized as follows:

- In the LA high density air traffic scenario, this analysis concludes that A3 aircraft should be capable of participating with other A3 aircraft in the applications defined in RTCA DO-242A which require State Vector and TS Report for ranges up to and including 40 NM. For applications that require State Vector only, the range is extended to 60-70 NM, depending on the interference environment.

- In the low density air traffic scenario, this analysis concludes that A3 aircraft should be capable of participating with other A3 aircraft in the applications defined in RTCA DO-242A which require State Vector and TS Report for all required and desired ranges.

- In the LA-[24k] (24,000 Mode A/C) high density air traffic scenario, this analysis concludes that A3 aircraft should be capable of participating with A2 aircraft in the applications defined in RTCA DO-242A which require State Vector only for ranges up to and including 40 NM. The exchange of TS Report information is limited to 20 NM between A2 and A3 equipage aircraft.

- In the LA-[24k] (24,000 Mode A/C) high density air traffic scenario, this analysis concludes that A2 aircraft should be capable of participating with A2 aircraft in the applications defined in RTCA DO-242A which require State Vector only for ranges up to and including 30 NM. The exchange of TS Report information is limited to 20 NM between A2 equipage aircraft.

- Neither A1 nor A0 equipage was evaluated for this analysis.

This analysis has not evaluated the effect of transmitting more detailed intent information, such as TCRs. Future revisions of these MOPS should consider modifying the transmit power requirement for A3 equipage, so that the minimum power corresponds to that assumed in this analysis. In addition, improved A2 performance could be achieved by modifying either or both of the MTL requirement and the enhanced decoding techniques used.

P.3 Performance Evaluation by MIT Lincoln Laboratory

MIT Lincoln Laboratory employed two simulation tools to determine ADS-B reception performance as a function of range for the LA (as defined in §P.2.3.1) and low density scenarios. The first tool is a pulse-level simulation, whose output gives the probability of correct reception of an Extended Squitter signal as a function of received signal power level. The second tool is a track-level simulation, whose input is the per-squitter reception probability from the pulse-level simulation, and whose output gives the performance over a time period, such as 12 seconds. When applied to long-range air-to-air surveillance, this simulation can be used to determine the maximum range at which 95 percent or more of the targets are being received sufficiently reliably to be in track and being updated regularly as required by the ADS-B MASPS (RTCA DO-242A).

P.3.1 Pulse Level Simulation

The pulse-level simulation generates a sample-by-sample received Extended Squitter signal in the presence of interference, consisting of Mode A/C fruit and Mode S replies and squitters, in both long and short formats. When used in this study, the interfering reception rates and power distributions were selected to match the interference environment in Los Angeles in two cases and the low density environment in the other. The interference rates and power distributions are described below.

P.3.1.1 Formulation of the Pulse-Level Simulation

This simulation was originally created for developing enhanced reception techniques for Extended Squitter. The simulation represents signals and interference as 1090 MHz radio frequency waveforms having amplitude and phase, so that destructive and constructive summation is represented. Each transponder is assigned a specific carrier frequency, which need not be exactly 1090 MHz. The frequency offsets were random, uniformly distributed over +/-1 MHz in this study. Minor pulse width deviations were also incorporated in this study. All pulses have rise times and fall times that correspond to the effects of both transmitter and receiver. The simulation can be run using different values of receiver bandwidth. Bandwidth was set equal to 8 MHz in this study. In addition to the received interference, the simulation also includes receiver noise, whose power was -100.7 dBm referred to the antenna in this study.

The received waveform, which is a sum of the Extended Squitter signal and all overlapping interference plus noise, is then converted to a log video waveform, which is sampled at a steady rate. These steps are illustrated in Figure P-16. The simulation can be run at a sampling rate of 8 samples per microsecond or 10 samples per microsecond. The rate of 8 per microseconds was used in this evaluation. The log video samples are then processed using the enhanced reception techniques. These techniques include an improved form of preamble detection, the 4-4 table method of declaring the 112 bits and associated confidence bits, and the error detection/correction technique called "Brute Force, n=5".

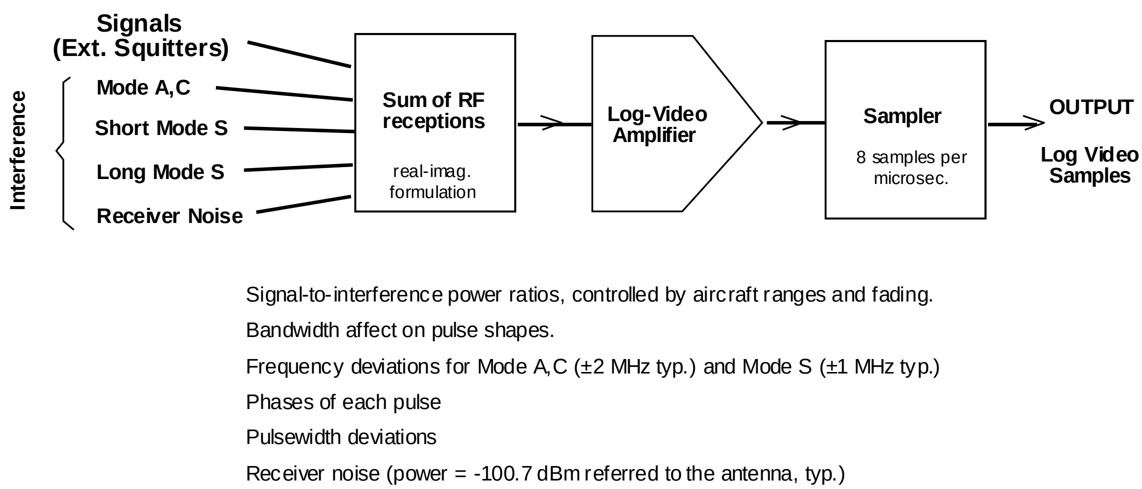


Figure P-16: Overview of the Pulse-Level Simulation

To generate reception probability as a function of received power level, the process is as follows. The user assigns a total number of aircraft (1000 aircraft for example) and provides a range distribution. The simulation generates the ranges of these aircraft using a pseudo-random process, following the given range distribution. Then for each aircraft, the nominal value of received power level is calculated using the following formula:

Nom. Received power (dBm at antenna) = -83.5 - 20 log10(range/100 NM)

The next step is to apply a random power deviation to account for both transmitter power differences from aircraft to aircraft and antenna gain effects. The user also assigns a transmission rate for each of the three types of signals. The simulation is run for a fixed time period set by the user, typically 10 seconds. For each transmitting aircraft, the transmissions are made random in time, uniformly distributed over the run time. The reception times are modeled as a Poisson process, having a constant average reception rate for each of the three types of signals.

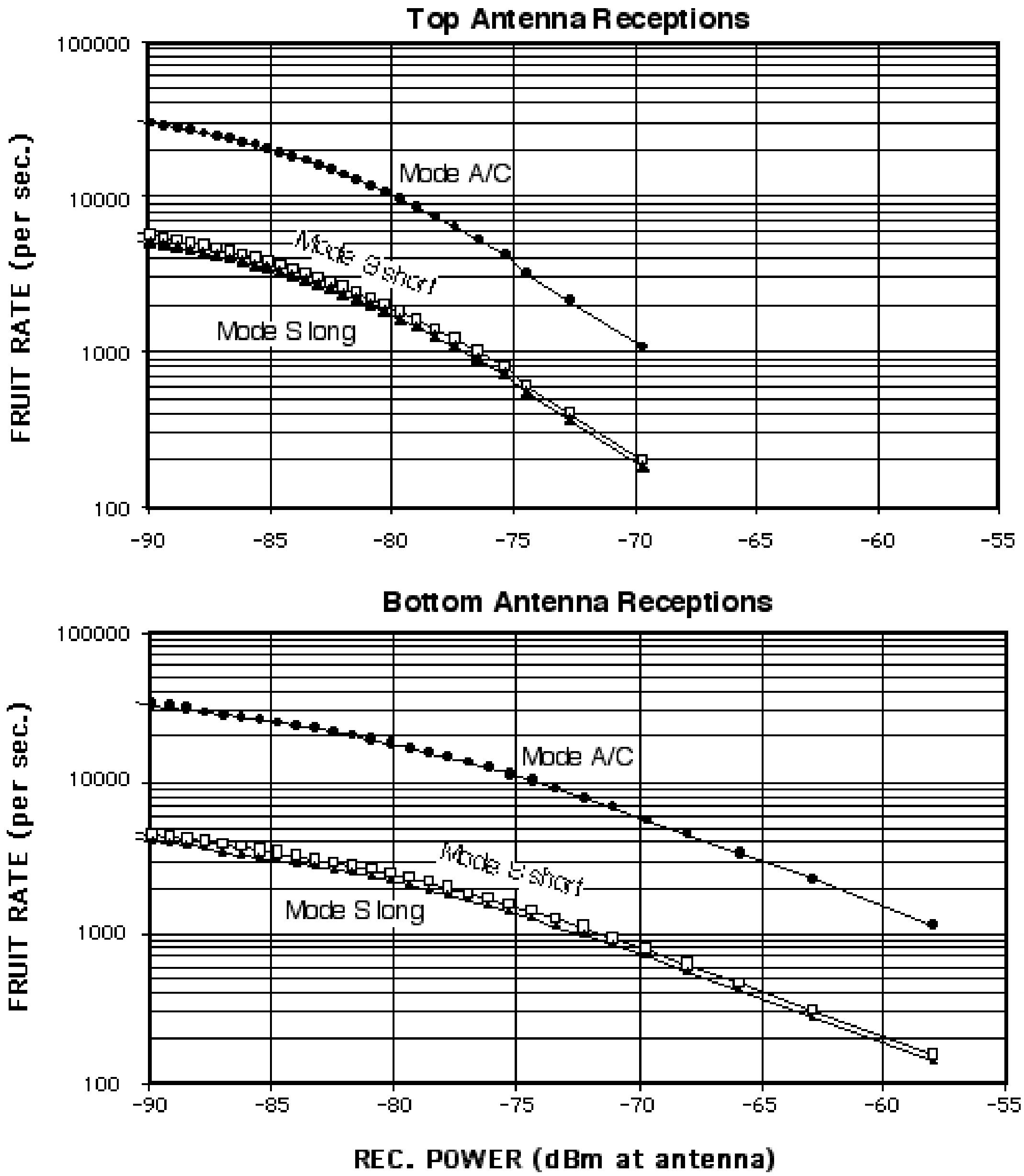
These particular assignments of nominal power and power deviations are used only in the pulse-level simulation, and only for the purpose of generating a fruit distribution appropriate for the environment being studied.

As each Extended Squitter is received, it is processed to determine whether the 112 bit message is correctly received, including the effects of error detection/correction. All such receptions, whether correct or not, are saved in bins according to the received power level. Five-dB bins were used in this study. After the full run, which includes several thousand reception opportunities in each of the major bins of interest, the number of correct receptions in compared with the total number of opportunities. The probability of correct reception is computed as the ratio:

Probability of correct reception = (no. of correct receptions)/(no. of opportunities)

P.3.1.2 Interference Rates and Power Distribution

In running the pulse-level simulation for the Los Angeles environments, it was necessary to specify the rates and power distributions of the interfering signals. For Los Angeles, this was done based on results from airborne measurements in the LA Basin in 1999 and on results from the Volpe simulation [Reference P-3]. It was found that the power distribution of Mode A/C fruit from the LA Volpe simulation agrees with the airborne measurements above –75 dBm, except being higher in fruit rate, which would be expected because of the future higher aircraft densities. The Volpe results were then used to provide the fruit-rate input to the Lincoln Laboratory pulse-level simulation. Figure P-17 shows the Mode A/C and Mode S fruit rates and power distributions used as inputs for this study. This applies to a scenario called “LA-[24k],” in which the receiving aircraft is located near LAX airport at 40,000 feet altitude. Mode S interference is characterized by short Mode S transmissions from each aircraft at a rate of 6 per second, and long Mode S transmission at a rate of 5.4 per second. The total Mode A/C fruit rate when referred to a power level of -84 dBm at antenna is 24,000 fruit per second, for bottom antenna receptions. For top antenna receptions the corresponding fruit rate is 18,000 fruit per second.



<u>Figure P-17:</u> Top and Bottom Antenna Fruit, LA-[24k]

P.3.1.3 Pulse-Level Simulation Results for A3 to A3

The pulse-level simulation was run for the LA scenario with two different cases of fruit levels representing different interference environments for future higher aircraft densities. The first case called "LA-[24k]" has 24,000 Mode A/C fruit per second, as described above. The second, more severe case, called "LA-[30K]," has 30,000 Mode A/C fruit per second, with the same Mode S interference as in LA-[24k]. The pulse-level simulation results are shown in Figure P-18 for Air-to-Air performance of A3 to A3.

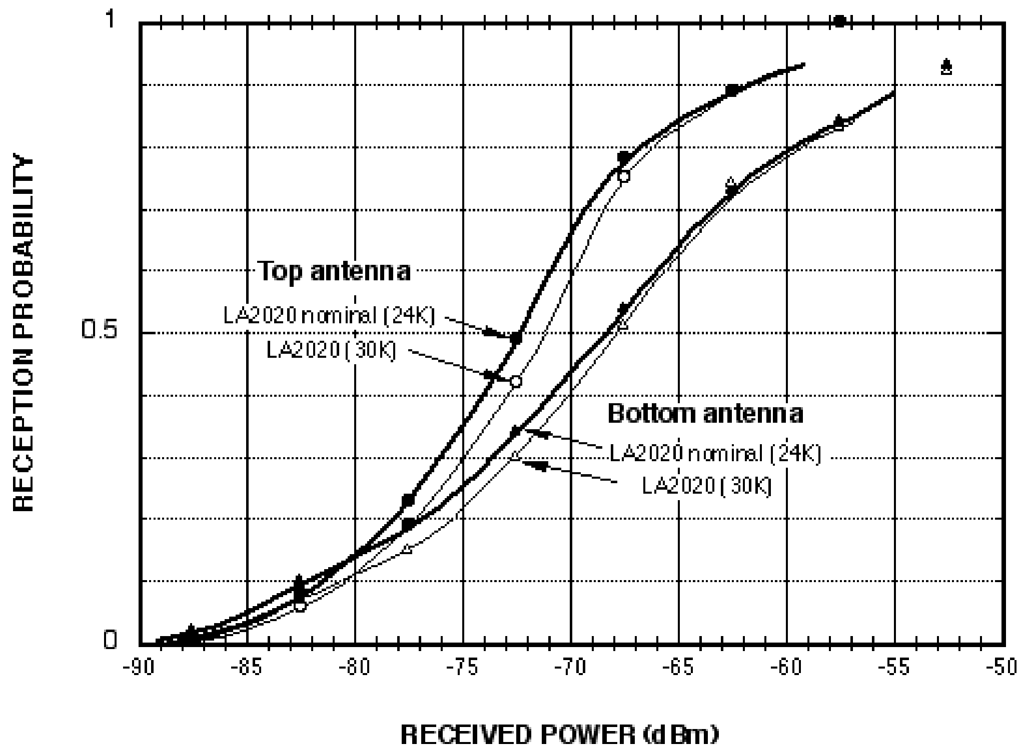


Figure P-18: Reception Probability versus Received Power for A3-to-A3

P.3.1.4 Pulse-Level Simulation Results for A2

The pulse-level simulation is used to determine reception probability as a function of received signal power level. The simulation results, plotted in Figure P-19, show a comparison between MTL = -79 dBm (Class A2) and MTL = -84 dBm (Class A3), for the LA-[24k] environment.

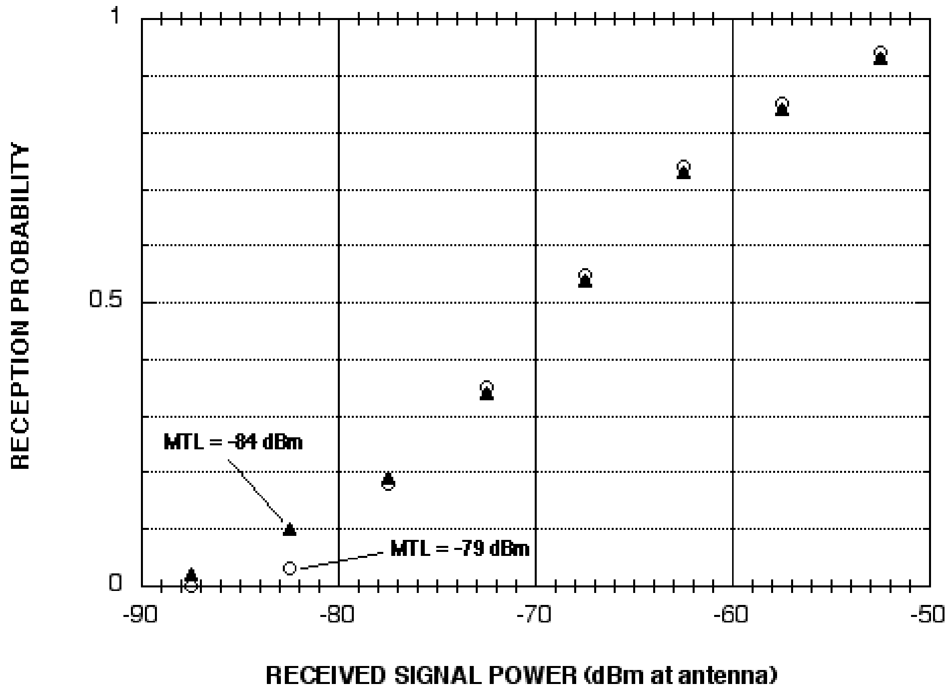


Figure P-19: Pulse-Level Simulation Results (bottom antenna receptions)

The results indicate that the only significant effect is near MTL. Class A2 reception probability is reduced in the vicinity of the MTL power level, and otherwise nearly the same as for Class A3. A curve fit was applied to the data in Figure P-19, for use in the Track-Level Simulations and is shown in Figure P-20.

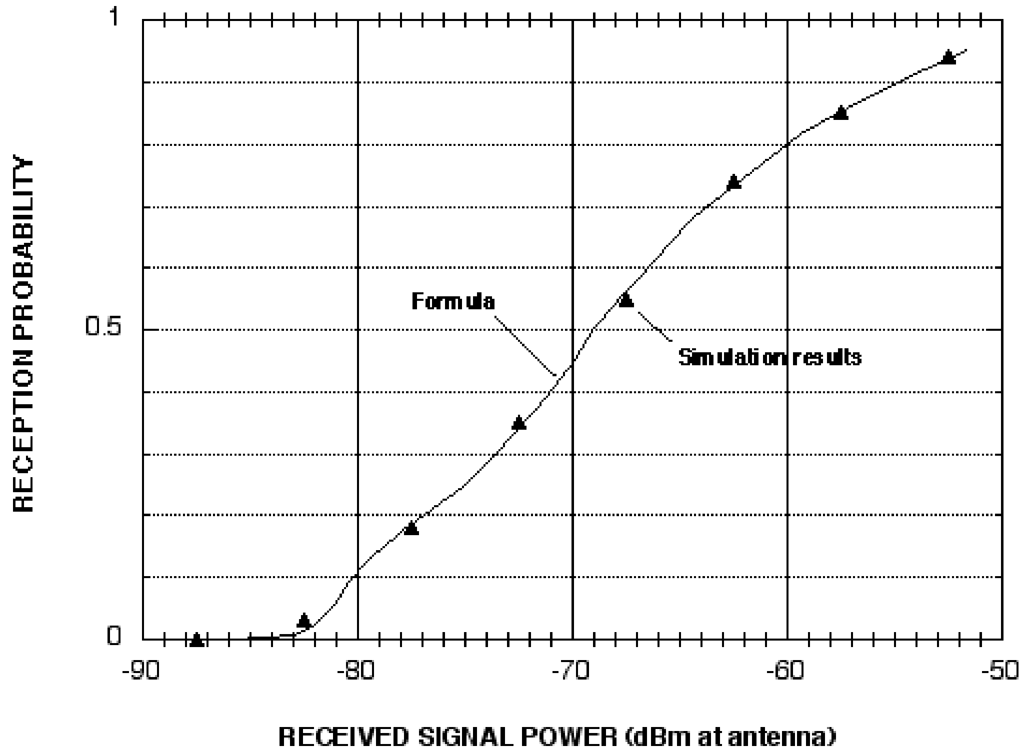


Figure P-20: **Curve Fit to Simulation Results**

P.3.2 Track-Level Simulation

After the pulse-level simulation has generated results in the form of reception probability as a function of received signal power, the track-level simulation can be used to determine system performance.

P.3.2.1 Formulation of the Track-Level Simulation

The track-level simulation is formulated using a Monte Carlo technique in which one run represents one pair of aircraft at a given air-to-air range. In each run, pseudo random variables are used to generate the antenna gain values and the transmitter power for that particular transmitting aircraft.

The TLAT model is used for the statistical variation of aircraft antenna gains. The scenario considered in these runs applies to altitudes that are nearly the same, and for which the antenna vertical patterns are not used. Altitude differences were studied separately, as described below.

After being generated at random, the antenna gain values are held constant for that particular pair of aircraft. The cases being addressed in this study apply to antenna diversity on both the transmitting and the receiving aircraft. Therefore each aircraft pair has four antenna gain values. These four values are generated independently in the simulation. Transmitter power is generated at random using a given distribution. For a Class A3 aircraft, is modeled as uniformly distributed over 53 to 56 dBm referred to the antenna.

The simulation is run for a particular air-to-air range. Using the transmitter power and the four antenna gains, the four values of received power are calculated (top-to-top, top-to-bottom, bottom-to-top, and bottom-to-bottom). For each case the probability curve (from the pulse-level simulation) is then used to determine the reception probability for that particular antenna combination.

Receiver blanking caused by co-site interference is included at this point. The values of reception probability calculated as above are now multiplied by 0.93 to account for these effects.

To account for receiving antenna diversity, the probability of correct reception is calculated using the following formula:

$$\text{Prob(correct)} = \text{Maximum}[P(\text{top}) , P(\text{bot})]$$

where **P(top)** and **P(bot)** are the reception probabilities for top only and bottom only. In other words, only the better of the two receiving antennas is used; the other does not contribute to performance.

Subsequently, to account for transmitting antenna diversity, the reception probability is calculated separately for top-transmit and bottom-transmit, and then these two values are averaged. This averaging is based on the fact that each antenna transmits 50 percent of the squitters.

This process yields the value of reception probability for a particular pair of aircraft. The process is repeated for a large number of aircraft pairs (1000 pairs). Performance for the 95th percentile pair is determined by sorting the 1000 values and identifying the value that is exceeded by 95% of the population. This result gives the 95-percentile reception probability for the range being considered. Repeating the process for different ranges provides system performance as a function of range.

P.3.2.2 Track-Level Simulation Results for A3-to-A3

For the LA-[24k] scenario, both the pulse-level simulation and the track-level simulation were run, yielding the results given in Table P-2, and shown in Figure P-21 and Figure P-22.

Table P-2: LL A3-to-A3 Performance as a Function of Range for LA-[24k]

RANGE NM	Prob (95) Reception Probability	T95/95 second
10	0.681	0.7
20	0.429	1.3
30	0.272	2.4
40	0.185	3.7
50	0.130	5.4
60	0.106	6.7
70	0.077	9.3
80	0.058	12.5
90	0.055	13.2
100	0.045	16.3

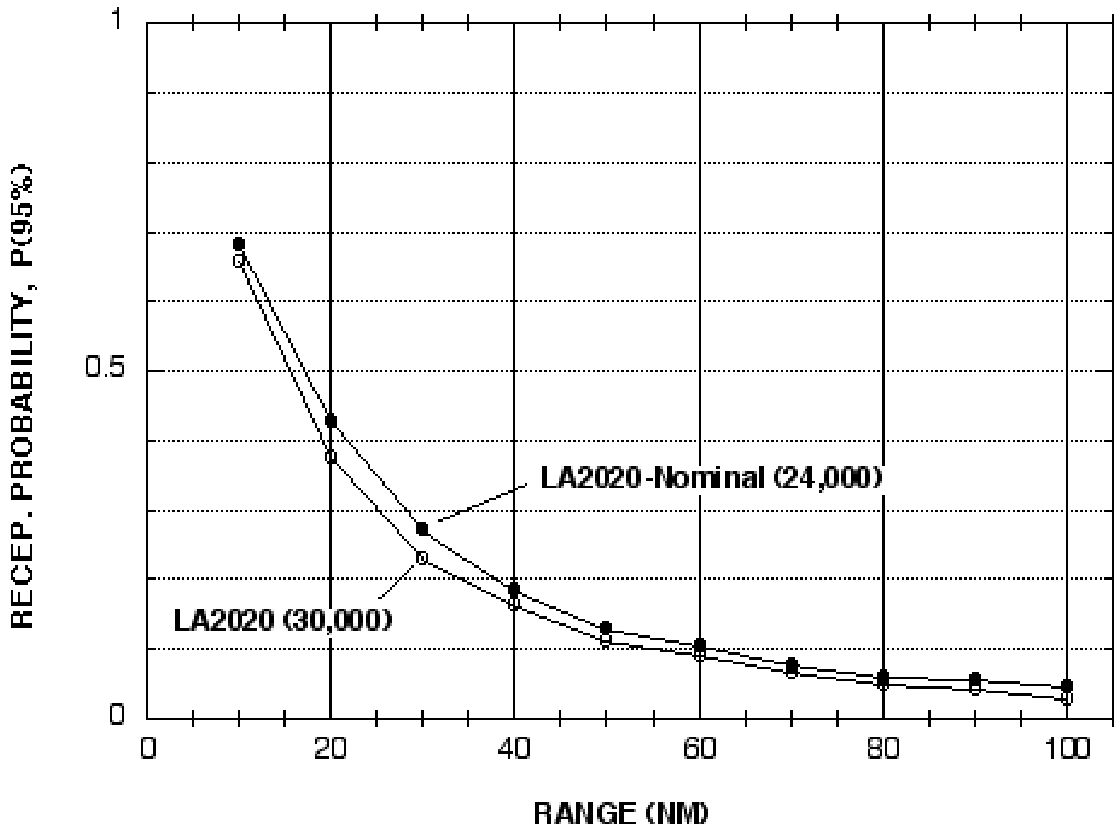


Figure P-21: **Future A3-to-A3 System Performance in the Los Angeles Basin**

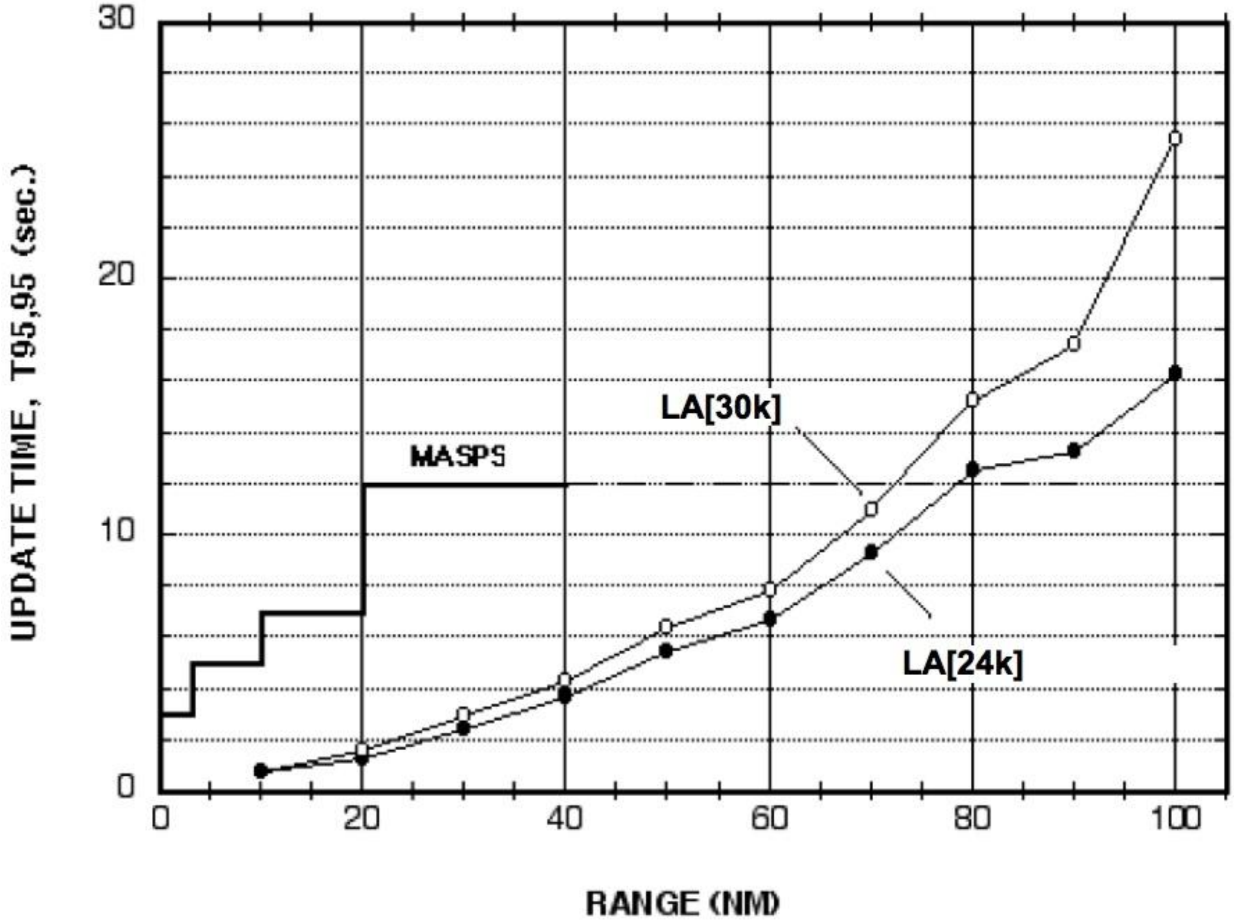


Figure P-22: State Vector Update Performance for A3-to-A3

The results in Figure P-22, showing State Vector update time, were generated from the probability values as follows. In a time **T**, the number of reception opportunities is:

$$N = T / 0.25 \text{ seconds.}$$

Given the reception probability from the pulse-level simulation, the probability of correct reception during the time **T** is therefore:

$$P(\text{recep. in } T) = 1 - (1 - p1)^N$$

where **p1** is the single-squitter reception probability. Requiring 95% reception in time **T**, or **P(recep. in T) = 0.95**, the solution for time **T** is:

$$T95 = 0.25 * \ln(0.05) / \ln(1 - p1)$$

This calculation is made for each pair of aircraft among 1000 pairs. The results are sorted, in order to determine the **T95** value for which performance is as good or better for 95% of the aircraft pairs. The result is denoted **T95/95** to indicate that it applies to 95% surveillance update reliability for 95% of aircraft pairs.

P.3.2.3 Track-Level Simulation Results for A2-to-A2

Using the curve fit shown in Figure P-20, the Track-Level simulation was run for 1000 aircraft pairs (one aircraft transmitting and one receiving). The formulation of the simulation is documented in §P.3.2.1. The simulation includes co-site interference in the form of 93% receiver availability.

For the case of A2 to A2 aircraft pairs, the results are shown in Table P-3.

Table P-3: LL Simulation Results for A2-to-A2 in LA [24k]

Range NM	Reception Prob 95 percentile	State Vector T95/95 (sec.)	TS Report T95/95 (sec.)
10	0.597	0.8	4.1
15	0.418	1.4	6.9
20	0.333	1.8	9.2
25	0.255	2.5	12.7
30	0.209	3.2	16.0
35	0.145	4.8	23.9
40	0.105	6.8	33.8
45	0.068	10.6	53.2
50	0.048	15.2	76.1
55	0.032	23.0	115.1
60	0.014	53.1	265.6

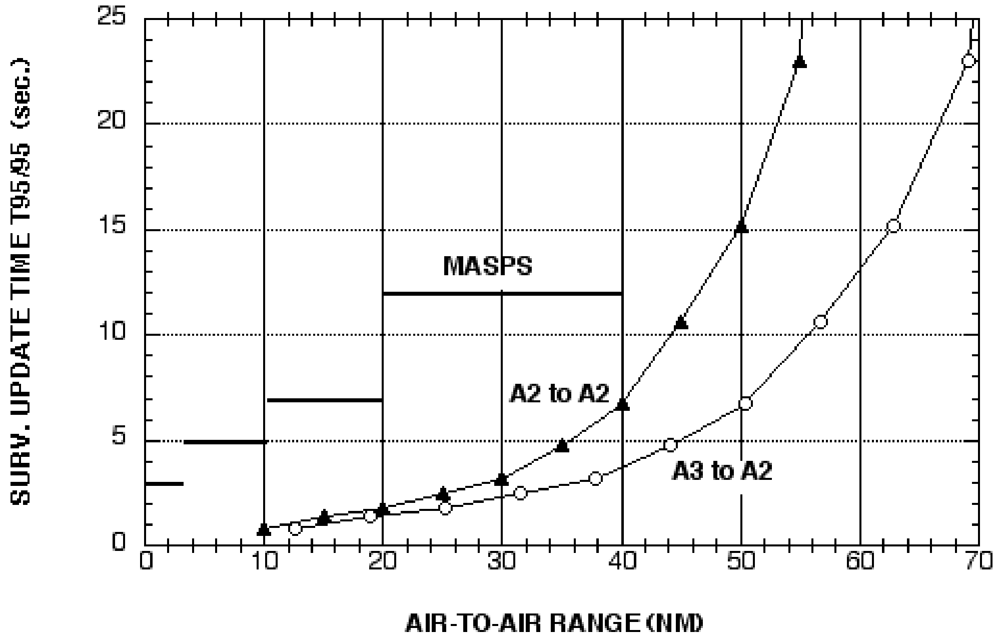
P.3.2.4 Track-Level Simulation Results for A3-to-A2

The other case to consider is Class A3 transmissions received by Class A2 aircraft. The only difference between this case and the first case is the higher power level of the A3 transmitters. In the model being used, A3 transmitters are between 53 and 56 dBm whereas Class A2 transmitters are between 51 and 54 dBm. This difference affects the results as a 2 dB change in ranges for each level of performance. Therefore the results in Table P-3 can be converted to the results in Table P-4 for the A3 to A2 case.

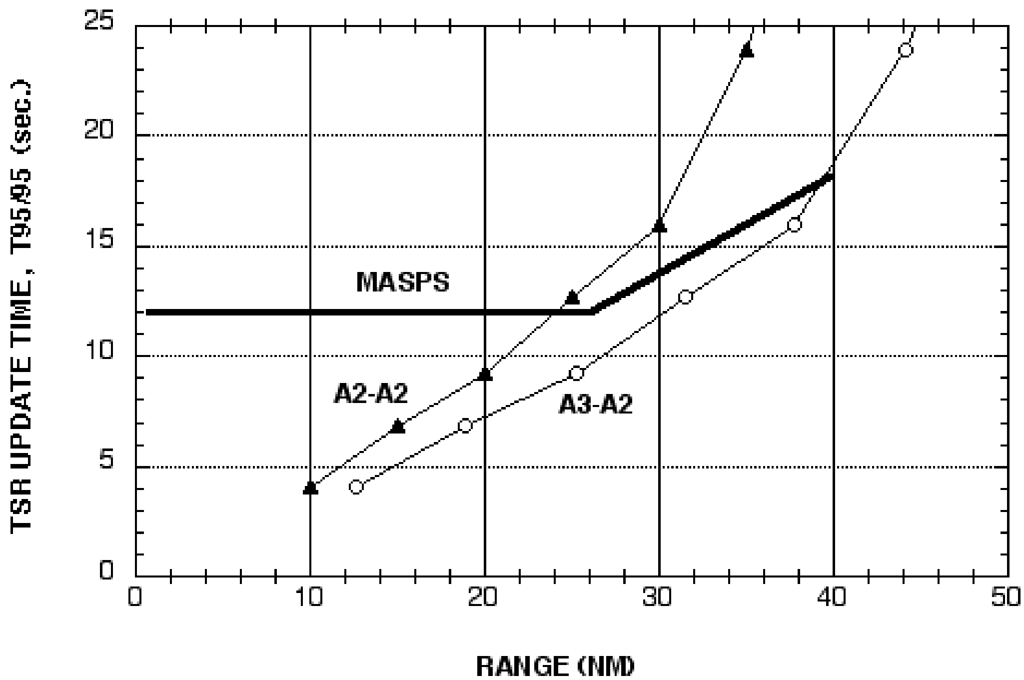
Table P-4: LL Simulation Results for A3-to-A2 in LA [24k]

Range NM	Reception Prob 95 percentile	State Vector T95/95 (sec.)	TS Report T95/95 (sec.)
12.3	0.597	0.8	4.1
18.9	0.418	1.4	6.9
25.2	0.333	1.8	9.2
31.5	0.255	2.5	12.7
38	0.209	3.2	16.0
44	0.145	4.8	23.9
50	0.105	6.8	33.8
57	0.068	10.6	53.2

These results are plotted in Figure P-23 and Figure P-24, where they are compared with the ADS-B MASPS (RTCA DO-242A) standards. Air-to-air surveillance is seen to satisfy the MASPS standards in both cases, A2-to-A2 and A3-to-A2. Air-to-air communication of TS Report information (Figure P-24) satisfies the MASPS standards for A3-to-A2, whereas in the case of A2-to-A2, performance falls short of the MASPS beyond about 24 NM.



<u>Figure P-23:</u> State Vector Update Rate for A3-to-A2 in LA [24k]



<u>Figure P-24:</u> TSR Update Rate for A3-to-A2 in LA [24k]

P.3.3 Effects of Altitude

In the normal formulation, the two aircraft are considered to be at approximately the same altitude, and therefore the elevation-angle portion of the antenna gain model was not used (only the statistical portion was used). For an additional study of altitude effects, the formulation was changed so that the transmitting aircraft has a specific altitude (a parameter entered by the user) while the receiving aircraft is at the fixed altitude of 40,000 feet. Therefore the results depend on the transmitter altitude. The TLAT model of aircraft antenna gain as a function of elevation angle was used in this study [Reference P-1].

The results for several values of transmitter altitude are shown in Figure P-25 and Figure P-26. The results indicate that performance is somewhat degraded when the transmitter is changed from 40,000 feet to 5000 feet. The degradation is more pronounced at shorter range, which seems reasonable because of the steeper elevation angles. Beyond 50 NM, performance is not changed significantly.

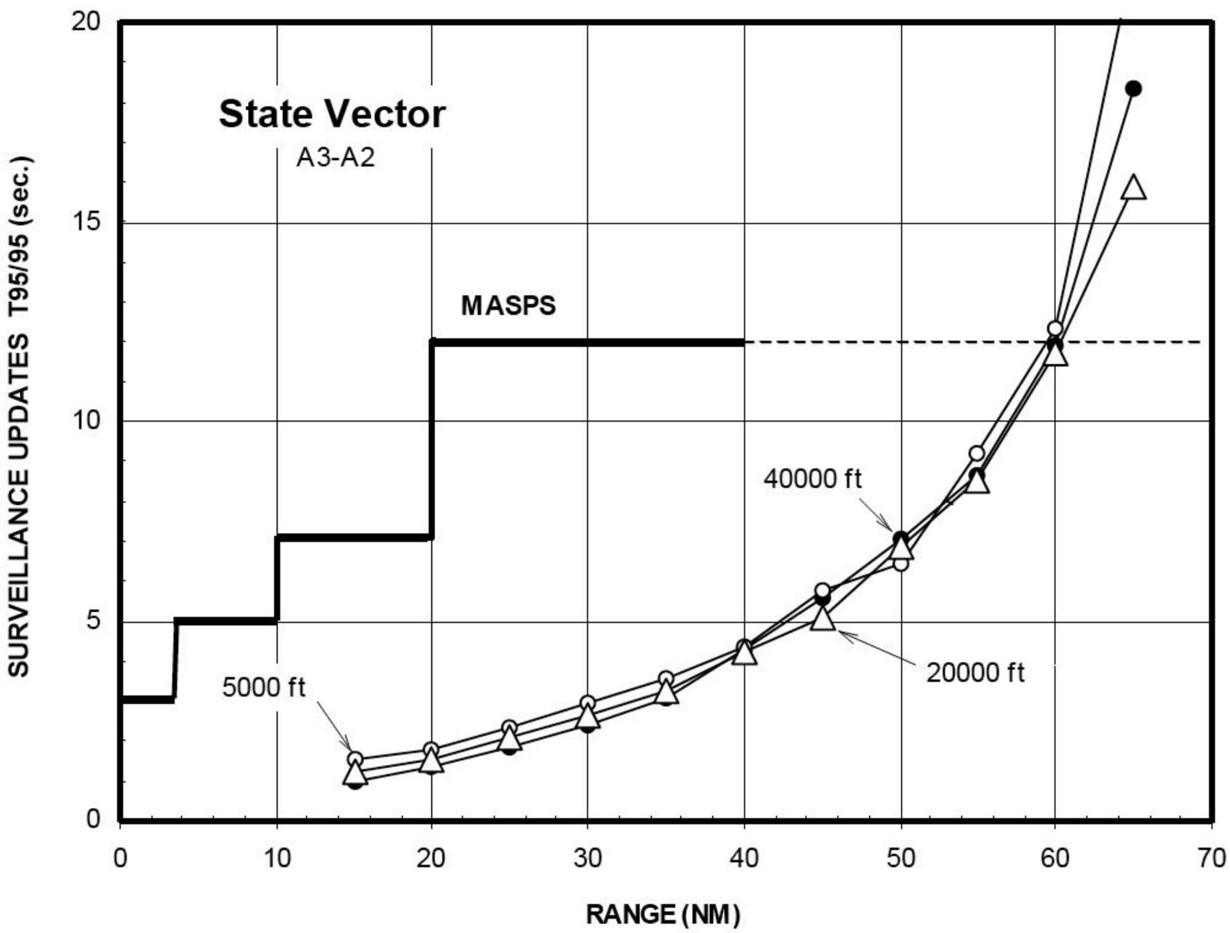


Figure P-25: Effects of Transmitting Aircraft Altitude (A3-A2, LA-[24k]) on State Vector

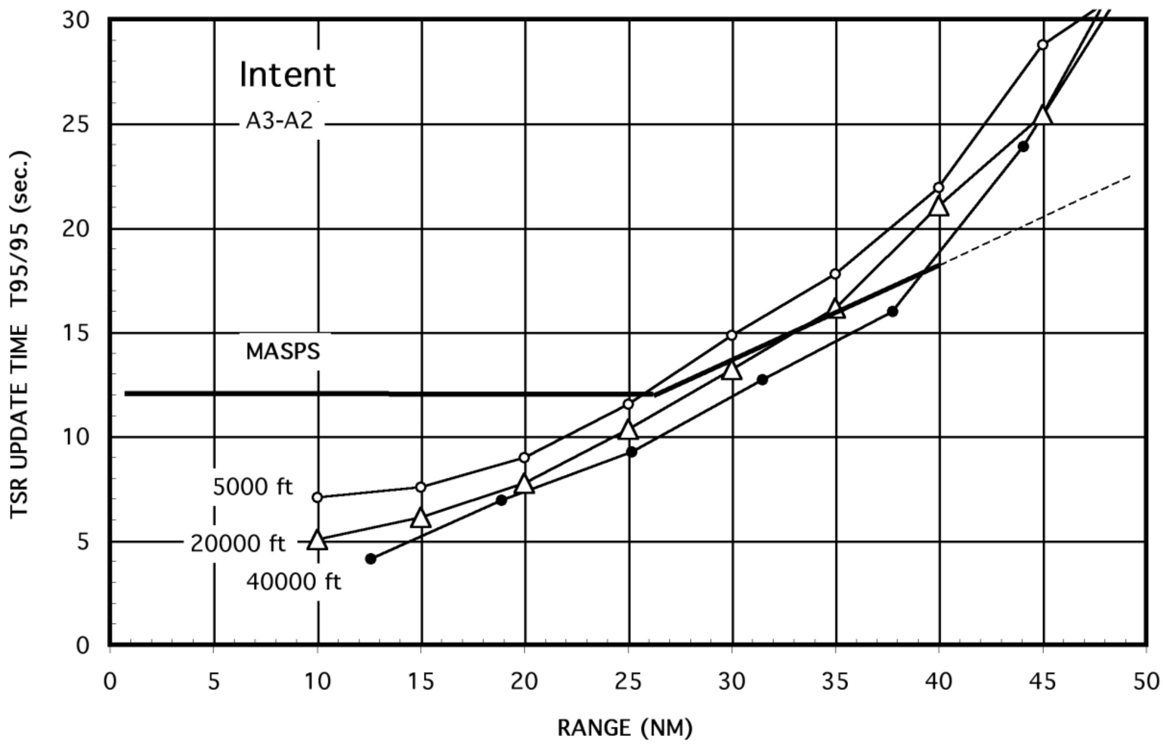


Figure P-26: **Effects of Transmitting Aircraft Altitude (A3-A2, LA-[24k]) on TSR Update Rate**

Note: *Altitudes marked in the figure apply to the transmitting aircraft. The receiving aircraft is at 40,000 feet.*

Looking at intermediate results from the simulation, one can see several reasons why altitude would not be expected to have much effect at long range. For long range, the elevation angle change is small. For example, for range of 100 NM and transmitter altitude of 5000 feet, the elevation angles are +/-3.3 degrees. According to the TLAT antenna gain model, this causes a drop by only 1.1 dB for one antenna and a boost by 1.0 dB for the other. The effects are small and nearly identical.

Figure P-26 indicates that the slope of the performance curves is similar to the slope of the TSR requirement. As a result, the relatively small degradation in TSR performance in this figure causes the MASPS intersection point to drop more dramatically. Although the MASPS requirement is not strictly met beyond that point, the performance is only a few seconds different from the requirement.

In conclusion, the results from the normal runs, in which altitude differences were not used, have been shown to be accurate at long ranges, regardless of the actual altitude of the transmitting aircraft. The results indicate that performance is not very sensitive to transmitter altitude between 20,000 feet and 40,000 feet, although sensitivity increases for very low transmitters.

P.3.4 Higher Fruit LA Environment

In performing the evaluation for the higher-fruit case, 30,000 Mode A/C fruit per second, the same process was followed. The results are included in Figure P-21 and Figure P-22.

P.3.5 Low Density Environment

The Low Density Environment defined in the ADS-B MASPS (RTCA DO-242A) was also evaluated. The aircraft are uniformly distributed in area over a circle of 400 NM radius. The total number of aircraft is 360, so the density is 0.0007 aircraft per square NM.

P.3.5.1 Reception Probability versus Signal Power

In evaluating performance in this environment, the first step was to determine reception probability as a function of range. The conclusion is that the MTL curve by itself is an appropriate characterization of reception performance as a function of received power in the low density environment. The MTL curve used in this evaluation was based on bench tests performed at the FAATC. The curve satisfies both MTL requirements (90% at -84 dBm and 15% at -87 dBm) and is otherwise the worst-case curve.

P.3.5.2 Low Density Environment Track-Level Simulation

The track-level simulation was then run, using the same procedure as was used for LA-[24k] except for the probability input curve, which embodies the characteristics of the low density environment. The runs apply to Class A3 transmissions received by Class A3 aircraft. Both aircraft have antenna diversity. A receiver dead time factor of 0.93 was also used.

The simulation results are given in Table P-5 and shown in Figure P-27 and Figure P-28. These results exhibit more statistical fluctuations than in the previous cases, which can be attributed to the abruptness of the MTL curve. As a result, the simulation was run twice at each range. Both points were tabulated and plotted, to indicate the degree of accuracy in these results as influenced by the number of trials (1000 aircraft pairs contributing to each point).

Table P-5: LL Performance in the Low Density Environment

Range NM	Reception Probability P(95)	T95/95 seconds
70	0.696 0.676	0.629 0.665
80	0.481 0.552	1.142 0.933
90	0.465 0.465	1.197 1.197
100	0.465 0.465	1.197 1.197
110	0.464 0.402	1.201 1.457
120	0.215 0.278	3.094 2.299
130	0.142 0.094	4.890 7.587
140	0.018 0.018	41.232 41.232

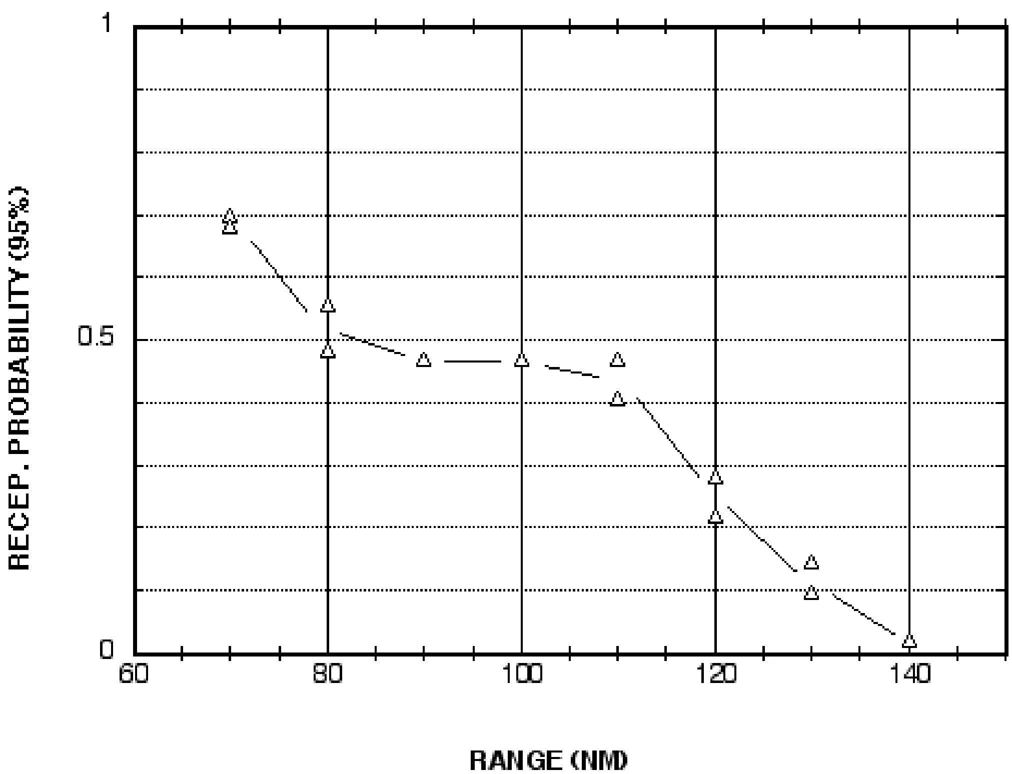


Figure P-27: Reception Probability in the Low Density Environment

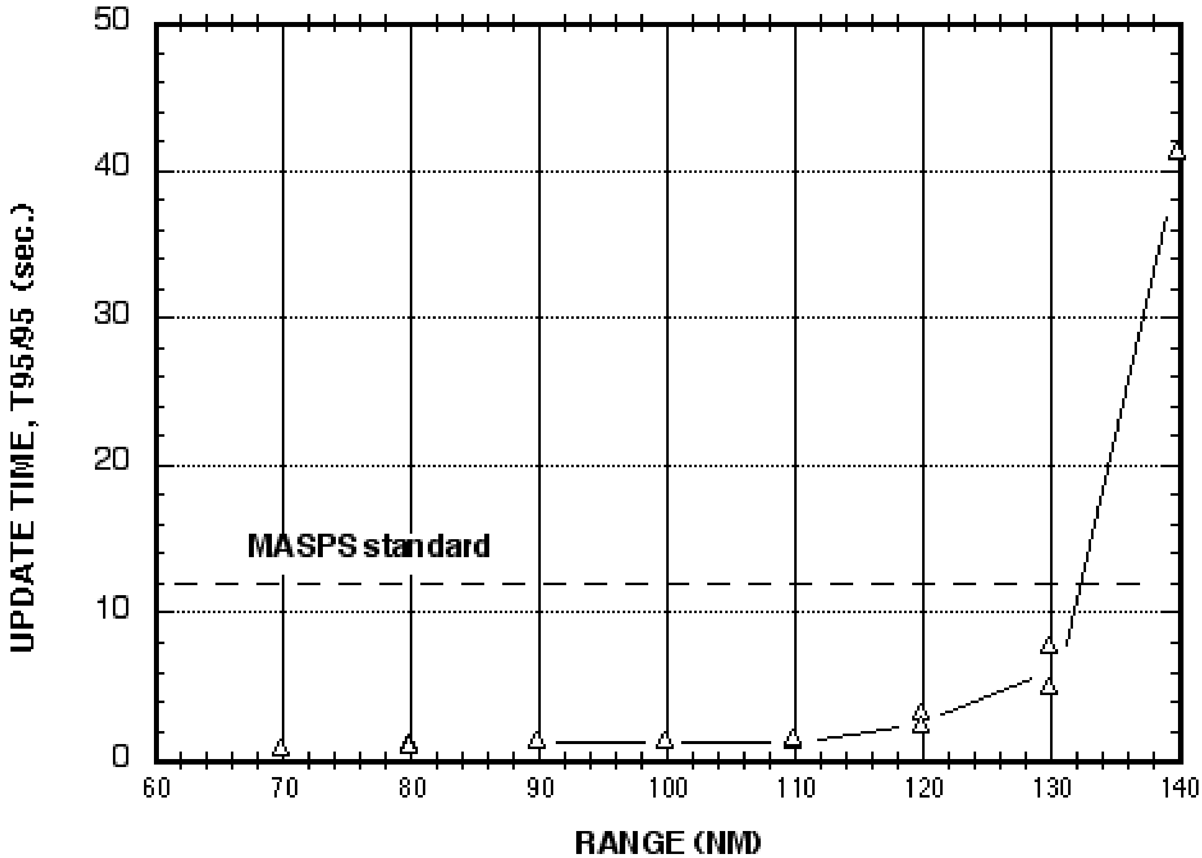


Figure P-28: State Vector Updates in the Low Density Environment for A3-to-A3 with 1250 Mode A/C Fruit

The results exhibit an interesting flat spot from 80 to 110 NM. Looking at this, one can see that it is a result of the steep MTL curve. It's not common, but occurs at around the 95 percentile worst cases, that one of the two transmitting antennas has higher power, for which reception is the maximum value (0.93), while the other transmitting antenna has lower power, for which reception is zero. Therefore the overall probability is (0.93 + 0)/2 = 0.465. This is the probability value at the flat spot.

The results in Figure P-28 indicate that the MASPS standards for State Vector are met out to about 130 NM air-to-air range for Class A3-to-A3. The same evaluation was performed for TS Reports, and the results indicate that the MASPS standards are met out to about 130 NM for Class A3-to-A3 avionics.

P.4 Summary of DO-260A Performance Analysis

Table P-6 and Table P-7 summarize the results from the simulations run by Johns Hopkins University Applied Physics Laboratory (APL), and by MIT Lincoln Laboratory (LL). These tables show to what range the report update requirements from the ADS-B MASPS, RTCA DO-242A where met for a given equipment class combination and Mode A/C fruit level. Also shown is the range to which the update requirements are required and desired as described in RTCA DO-242A.

Note: *For the high density scenarios of 24,000 and 30,000 Mode A/C fruit (see §P.1), RTCA DO-242A specifies that operational ranges are only to extend to 40 NM. However, it should be noted that as applications are developed and validated, these required ranges might be extended to 90 NM in high density airspace for A3 equipment.*

Table P-6: Simulation Summaries for State Vector Report Update Ranges

Transmitter	**Receiver**	**Mode A/C**	**APL**	**LL**	**RTCA DO-242A**	
					Required	**Desired**
A3	**A3**	24,000	70 NM	78 NM	40 NM	120 NM
A2	**A3**	24,000	50 NM	62 NM	40 NM	50 NM
A3	**A3**	30,000	60 NM	70 NM	40 NM	120 NM
A3	**A2**	30,000	**[1]**	53 NM	40 NM	120 NM
A2	**A3**	30,000	40 NM	55 NM	40 NM	50 NM
A2	**A2**	30,000	**[1]**	42 NM	40 NM	50 NM
A3	**A2**	24,000	40 NM	59 NM	40 NM	120 NM
A2	**A2**	24,000	30 NM	47 NM	40 NM	50 NM
A3	**A3**	5,000	>120 NM	115 NM	90 NM	120 NM
A3	**A3**	1,250	>120 NM	~130 NM	90 NM	120 NM

Table P-7: Simulation Summaries for Target State Report Update Ranges

Transmitter	**Receiver**	**Mode A/C**	**APL**	**LL**	**RTCA DO-242A**	
					Required	**Desired**
A3	**A3**	24,000	50 NM	40 NM	40 NM	50 NM
A2	**A3**	24,000	20 NM	32 NM	40 NM	50 NM
A3	**A3**	30,000	40 NM	28 NM	40 NM	50 NM
A3	**A2**	30,000	**[1]**	**[1]**	40 NM	50 NM
A2	**A3**	30,000	20 NM	28 NM	40 NM	50 NM
A2	**A2**	30,000	**[1]**	21 NM	40 NM	50 NM
A3	**A2**	24,000	20 NM	40 NM	40 NM	50 NM
A2	**A2**	24,000	20 NM	24 NM	40 NM	50 NM
A3	**A3**	5,000	>120 NM	115 NM	40 NM	50 NM
A3	**A3**	1,250	>120 NM	~130 NM	40 NM	50 NM

[1] - Not evaluated

The above summary tables show that the 1090 MHz ES ADS-B system, as defined in these MOPS, will meet the report update requirements from RTCA DO-242A beyond the required ranges for A3 equipment interacting with A3 equipment at recommended power levels. It should be noted, however, that if the operational range of 40 NM for high density airspace would be increased to that of 90 NM used for low-density airspace, the performance of the 1090 MHz ES system would not meet the update requirements through that extended range.

For State Vector update performance, the requirements for RTCA DO-242A are also met for A3 equipment interacting with A2 equipment at recommended power levels. Performance requirements up to 40 NM for State Vector updates will be met in the high density environments between A3 and A2 equipment, however, results are unclear if A2-to-A2 communications will meet the 40 NM requirement in LA. The results show that update requirements will not be met in high density airspace for the TS Reports for A2 equipment interfacing with either A2 or A3 systems.

The transmission rate for A2 equipment has been selected in light of the current 6.2 transmissions per second limit and is tailored to A3 equipment, and retains capability to support the Trajectory Change Reports (see Appendix O). Future editions of these MOPS may consider increasing the transmission rate of short term intent information supporting TS Reports for A2 equipment in order to provide longer range performance in the highest density environments.

As described in §P.3.3, relatively small variations in predicted TSR performance may result in significant differences in the ranges at which the MASPS TSR updates rates are satisfied.

Table P-6 shows performance for the MASPS low density scenario with two different Mode A/C fruit rates. These results indicate for Mode A/C fruit rates approaching 5000 per second that the 1090 MHz system for A3-to-A3 interactions offers the MASPS desired range of 120 NM.

The performance results reported in Appendix P were derived from two independent evaluations, one by APL and the other by LL. Examination of Tables P-6 and P-7 shows (only) three differences in simulated performance results provided by APL and LL that impact the determination of whether particular RTCA DO-242A requirements are projected to be met by the 1090 MHz Extended Squitter system in the LA air traffic scenario (Table P-6, A2 transmitter and A2 receiver at 24,000 Mode A/C fruit; Table P-7, A3 transmitter and A3 receiver at 30,000 Mode A/C fruit; and Table P-7, A3 transmitter and A2 receiver at 24,000 Mode A/C fruit). A significant effort was made to understand the reason for any differences between the results reported by each evaluation. The APL and LL evaluation techniques, while using similar assumptions on, for example, probability of correct reception of a single Extended Squitter as a function of received signal power, use different simulator architectures and, for A3 receivers, a different sampling rate. These differences, in conjunction with uncertainties inherent in the simulation processes, are the likely source of the differences in the values for update ranges obtained.

P.5 Additional Performance Analysis for DO-260B

Additional analysis was carried out for the publication of DO-260B, in order to examine the performance of 1090 ES in more dense traffic environments and evaluate the performance of the newly-defined single-antenna A1 category of equipage. In order to be consistent with the performance metrics used in the rest of this appendix, it was decided to use the same update interval benchmarks that were used in the previous Appendix P that was done for DO-260A. These benchmarks were based on initial estimates of the application requirements provided by the ADS-B MASPS (DO-242A) that were published in 2002. Since the publication of DO-260A, much work has been done to refine the air-to-air applications and the accompanying requirements, so these benchmarks may have changed. Nevertheless, for consistency this section will use the DO-242A values. For further information on more recent update interval requirements, see DO-289, DO-312, and DO-314. In addition, there is ongoing work to define new air-to-air applications.

P.5.1 East Coast Air Traffic Scenario

A new air traffic scenario was developed for this analysis. Since ADS-B will be sharing the 1090 MHz frequency with existing SSRs, TCAS, and other systems, understanding the current interference environment is necessary to provide confidence in the predictions of future interference environments in which the system will need to operate. The Northeast corridor of the United States was the selected environment to base future air traffic and interference predictions since high air traffic density, TCAS equipage, and SSRs contribute to a high 1090 MHz environment. There were several data recordings and measurements that were utilized to compile air traffic counts and flight tests to measure 1090 MHz interference rates. Initial analysis of air traffic counts were derived from the Enhanced Traffic Management System (ETMS) data from the Northeast in 2004. Based on Instrument Flight Rules (IFR) traffic measurements and the estimated of IFR to Visual Flight Rules (VFR) operations, the total traffic estimate was compiled.

A flight test was conducted on January 26th, 2006 in the Northeast corridor of the United States for the purpose of measuring and assessing 1030/1090 MHz activity. The 1030 MHz measurements were collected to help identify the source of 1090 MHz interference signals since interrogations on the 1030 MHz frequency produce ATCRBS and Mode S replies on the 1090 MHz frequency. Interference measurements on 1090 MHz included both ATCRBS and Mode S rates along with associated power levels to characterize the signal distributions received by instrumentation on the flight test aircraft. ATCRBS reply rates on 1090 MHz vary greatly over time and location.

An additional flight test was conducted on July 25, 2007 where 1030 and 1090 MHz measurements similar to the January 2006 flight test were taken. The traffic counts during this flight test were higher than the January 2006 flight test and one of the reasons for this was that the flight test was conducted during the afternoon peak traffic interval. The peak traffic time was missed in the January 2006 flight test which resulted in lower aircraft densities.

The air traffic scenario used to predict the current and future interference environments was derived from the data collected during the July 2007 flight test. The distribution of the traffic was captured by taking ‘snapshots’ of all aircraft seen by as many as 33 east coast enroute and terminal radars. The composite picture was created by converting the measured radar coordinates of all the aircraft at the time of the snapshot into latitude and longitude, superimposing the pictures seen by all the radars, and eliminating duplicate reports of the same aircraft as seen by multiple radars.

Work with the scenarios showed how critical things like aircraft distribution in range and altitude were when creating the predicted fruit rates. As a result, a significant effort was made to develop a new baseline model for 2007 that matched characteristics of the measured data as much as possible.

The scenario for generation of 1090 interference for the future years was based on a new model based on the results of the flight of 25Jul07. The measured results from the flight were characterized in detail so that the parameters of the model could be adjusted to match the contribution of each type of interference to the source of a particular type. The distribution of aircraft as a function of range and altitude was defined from the measured data. The percentage of each fruit type was also defined from the test data. The rates of the various types of interference varied considerably as a function of aircraft position.

The various parameters of the model were then adjusted until the percentage of Mode S contribution of the scenario matched the table values for the number of aircraft present during the flight test of 25Jul07. The number of aircraft was normalized to 1000 within 300 miles of the victim for this purpose. The actual number varied depending on the position of the aircraft at the time. This number of aircraft was then increased to produce Environments 1 through 4. The aircraft density at 6 miles was held constant at the value measured during the flight of 25Jul07. It was allowed to grow at further ranges according to the predicted distribution as a function of range. The total number of aircraft predicted for Environment 4 was 3000 within 300 miles.

P.5.2 Interference Environments

The 1090 ES ADS-B air-to-air performance was evaluated using four different interference environments, labeled Environments 1-4, derived from the East Coast Scenario. The four environments are categorized in Table P-8 below. The Mode S and ATCRBS numbers represent the number of those interference types at or above a signal level of -84 dBm.

Note: *The current environment as measured was approximately 384 aircraft within a radius of 100 NM, and somewhere between 1,100 and 1,200 aircraft within a radius of 300 NM. The factors in the first column of Table XX indicate the growth in the numbers of aircraft within 100 NM.*

Table P-8: Four Interference Environments for Evaluating A1S Air-to-Air ADS-B Performance

	Approx. No. AC in 100 NM	Approx. No. AC in 300 NM	Mode S (per sec)	ATCRBS (per sec)
Env 1 (x1.4)	**539**	**1,700**	**8,311**	**32,996**
Env 2 (x1.7)	**653**	**2,060**	**10,218**	**40,074**
Env 3 (x2.1)	**794**	**2,502**	**13,268**	**48,848**
Env 4 (x2.5)	**952**	**3,000**	**16,009**	**58,811**

P.5.3 Air-to-Air Performance Results

This section presents the air-to-air performance results in the four interference environments described in the previous section. All update intervals were calculated on the assumption that an update could be done upon receipt of either a position or velocity squitter. Some applications may put more stringent requirements on the nature of updates.

P.5.3.1 A1S Results

The single-antenna A1 category of ADS-B equipage (A1S) was evaluated for air-to-air performance using four different interference environments, labeled Environments 1-4, to determine its capability of participating in potential airborne applications. The analysis was done assuming that both transmitter and receiver were A1S equipped aircraft. The air-to-air ranges examined were 15 NM, 20 NM, 30 NM, and 40 NM. The update intervals used as benchmarks for these ranges, along with the A1S performance results for the different environments, are shown in Table P-9.

Table P-9: A1S Air-to-Air ADS-B Performance in Four Interference Environments

	T_{95}(3NM)	T_{95}(10NM)	T_{95}(20NM)	T_{95}(30NM)	T_{95}(40NM)
Update Int (95%)	**3 s**	**5 s**	**7 s**	**12 s**	**12 s**
Env 1	**1 s**	**8 s**	**25 s**	**X**	**X**
Env 2	**2 s**	**10 s**	**X**	**X**	**X**
Env 3	**2 s**	**15 s**	**X**	**X**	**X**
Env 4	**3 s**	**20 s**	**X**	**X**	**X**

An “X” in a box indicates that the value was very large. From the table, the A1S was unable to meet the update interval requirements past 3 NM for any of the high density environments considered.

P.5.3.2 A3 Results

The A3 category of ADS-B equipage was evaluated for air-to-air performance using the same four interference environments used to evaluate A1S, representing different numbers of aircraft within 300 NM of the victim receiver, labeled Environments 1-4, to determine its capability of participating in potential airborne applications in increasingly high air traffic density. The analysis was done assuming that both transmitter and receiver were A3 equipped aircraft. The update intervals used as benchmarks for these ranges, along with the A3 performance results for the different environments, are shown in Table P-10.

Table P-10: A3 Air-to-Air ADS-B Performance in Four Interference Environments

	T_{95}(3NM)	T_{95}(10NM)	T_{95}(20NM)	T_{95}(40NM)	T_{95}(60NM)
Update Int (95%)	**3 s**	**5 s**	**7 s**	**12 s**	**12 s**
Env 1	**1 s**	**1 s**	**2 s**	**8 s**	**23 s**
Env 2	**1 s**	**1 s**	**3 s**	**12 s**	**36 s**
Env 3	**1 s**	**2 s**	**4 s**	**33 s**	**X**
Env 4	**1 s**	**2 s**	**7 s**	**X**	**X**

An "X" in a box indicates that the value was very large. From the table, the A3 was able to meet the update interval requirements to 40 NM for two of the high density environments considered and to 20 NM for all of the environments.

REFERENCES:

P-1. "Technical Link Assessment Report," Safe Flight 21 Steering Committee, ADS-B Technical Link Assessment Team (TLAT), March 2001.

P-2. A. G. Cameron, et al, "The 1030/1090 MHz Interference Simulation Technical Description and Initial Results," TR-9454-02-01, TASC Inc., April 2001.

P-3. "Measurement of 1090 MHz Extended Squitter Performance In the Los Angeles Basin," DOT/FAA/ND-00/7, May 2000.

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Appendix Q

Proposed Future Runway Threshold Speed On-Condition Message

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Q Proposed Future Runway Threshold Speed On-Condition Message

Applications are under development that rely on knowledge of aircraft planned final approach speed. The requirements for these applications will be included in future RTCA documents and may be reflected in future versions of these MOPS. Until this work is concluded, this Appendix suggests a coding scheme for those desiring early implementation of this capability.

Q.1 Background

There are at least two applications under development that are expected to use planned runway threshold information to enhance airport capacity. The best documented is one that uses planned aircraft approach speeds for enhancing the capacity of converging runway configurations for airports such as Chicago's O'Hare. Potential capacity gains of 10-20 arrivals per hour in Instrument Meteorological Conditions (IMC) for such airports have been estimated (See Mundra and Smith, 2001). Another possibility is approach spacing. This analysis is currently underway, and may yield capacity benefits of the order of 3 to 4 arrivals per hour for any single runway operation under certain wind conditions.

To enable these procedures, the expected or planned speed of the aircraft across the threshold (i.e., the landing speed) must be known at least 10 to 15 minutes prior to touch-down. In practice, a logical time for computing and down-linking this speed is probably at top of descent. If transmitted more than 20 minutes before touch down, provision should also be made for at least one revised estimate.

This information would be input directly into terminal automation for aircraft spacing. This would thus be safety critical information and adequate reliability must be ensured, whether through redundancies or multiple transmissions.

Q.2 Information Content

Information should be in the following format:

Table Q-1: Proposed Runway Threshold Speed Encoding

Coding		Meaning (Runway Threshold Speed in knots in 1 knot increments)
(Binary)	(Decimal)	
000 0000	0	Runway Threshold Speed Not Available
000 0001	1	Runway Threshold Speed < 70 knots
000 0010	2	Runway Threshold Speed = 70 knots
000 0011	3	Runway Threshold Speed = 71 knots
000 0100	4	Runway Threshold Speed = 72 knots
…	…	…
111 1110	126	Runway Threshold Speed = 194 knots
111 1111	127	Runway Threshold Speed > 194 knots

The encoding in Table Q-1 represents positive magnitude data only.

Values of approach speed are assumed to be rounded to the nearest knot.

Q.3 Reference

Anand D. Mundra and Arthur P. Smith (2001), *Capacity Enhancements in IMC for Converging Configurations with down-link of aircraft expected final approach speeds*, 20th Digital Avionics Systems Conference, Dayton Beach, Florida, October 2001

Appendix R

Extended Squitter Broadcast Rate Analysis

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R Extended Squitter Broadcast Rate Analysis

R.1 Purpose and Scope

The purpose of this Appendix is to provide a calculation of 1090 MHz Extended Squitter broadcast rates for different operational scenarios to show that transmission rates achieved over a 60 second period meet the required average rate over 60 seconds, and that there is no need to implement a function to limit the total number of 1090 MHz Extended Squitters transmitted over a certain period of time.

R.2 Background

This version of these ADS-B MOPS, specifies different types of 1090 MHz Extended Squitters with different transmission rates (see Table 2-77)

There is no requirement to limit the transmissions over a 1 second period, other than a maximum of 2 Event-Driven Messages. The transmission rate averaged over 60 seconds must be less than or equal to 6.2 squitters per second.

R.3 Analysis of Extended Squitter Broadcast Rates for Specific Scenarios

R.3.1 Scenario 1: Airborne Steady State Conditions

Conditions:

- Airborne
- Target State and Status Message being broadcast

Table R-1: Airborne Steady State Conditions

	Time Between 2 Transmissions (seconds)	Average Number per Second	Peak Number per Second	Number over 60 Seconds	Comment
Airborne Position Message	0.5	2	2	120	
Airborne Velocity Message	0.5	2	2	120	
Aircraft Identification	5	0.2	1	12	
Target State and Status	1.25	0.8	1	48	
Aircraft Operational Status	2.5	0.4	1	24	
	0.8	1.25		-	
Aircraft Status	5	0.2	1	12	
	0.8	1.25		-	
Total number over the period			8	336	
Average /second				5.60	

R.3.2 Scenario 2: Airborne with Mode A Code Change

Conditions:

- Airborne
- Target State and Status Message being broadcast
- **Change in Mode A Code occurs**

Table R-2: Airborne with Mode A Code Change

	Time Between 2 Transmissions (seconds)	Average Number per Second	Peak Number per Second	Number over 60 Seconds	Comment
Airborne Position Message	0.5	2	2	120	
Airborne Velocity Message	0.5	2	2	120	
Aircraft Identification	5	0.2	1	12	
Target State and Status	1.25	0.8	1	48	
Aircraft Operational Status	2.5	0.4	1	24	
	0.8	1.25		-	
Aircraft Status	5	0.2	2	7	for remaining 36s
	0.8	1.25		30	for 24s after Mode A Code change + 36s RA
Total number over the period			9	361	
Average /second				6.02	

R.3.3 Scenario 3: Airborne, TSS, Permanent Alert State (7500, 7600, 7700)

Conditions:

- Airborne
- Target State and Status Message being broadcast
- **Permanent Alert State (7500, 7600, 7700)**

Table R-3: Airborne, TSS, Permanent Alert State (7500, 7600, 7700)

	Time Between 2 Transmissions (seconds)	Average Number per Second	Peak Number per Second	Number over 60 Seconds	Comment
Airborne Position Message	0.5	2	2	120	
Airborne Velocity Message	0.5	2	2	120	
Aircraft Identification	5	0.2	1	12	
Target State and Status	1.25	0.8	1	48	
Aircraft Operational Status	2.5	0.4	1	24	
	0.8	1.25		-	
Aircraft Status	5	0.2		-	
	0.8	1.25	2	75	for 60s
Total number over the period			9	399	
Average /second				6.65	

For this scenario the average number of Extended Squitters is greater than 6.2 per second. However, it can be considered that the occurrence of this scenario is a rare event, and if it happens it will be on a very limited number of aircraft in the coverage.

R.3.4 Scenario 4: Airborne, no TSS, NAC/SIL Change

Conditions:

- Airborne
- Target State and Status Message not being broadcast
- **Change occurs in the status of one or more of TCAS/NAC/SIL**

Table R-4: Airborne, no TSS, NAC/SIL Change

	Time Between 2 Transmissions (seconds)	Average Number per Second	Peak Number per Second	Number over 60 Seconds	Comment
Airborne Position Message	0.5	2	2	120	
Airborne Velocity Message	0.5	2	2	120	
Aircraft Identification	5	0.2	1	12	
Target State and Status	1.25	0.8	-	-	
Aircraft Operational Status	2.5	0.4		14	for 36s
	0.8	1.25	2	30	for 24s after a NAC/SIL change
Aircraft Status	5	0.2		12	
	0.8	1.25	1	-	
Total number over the period			8	308	
Average /second				5.13	

R.3.5 Scenario 5: Airborne, no TSS, TCAS/NAC/SIL Change, Mode A Code Change

Conditions:

- Airborne
- Target State and Status Message not being broadcast
- **Change in Mode A Code**
- **Change in the status of one or more of TCAS/NAC/SIL**

Table R-5: Airborne, no TSS, TCAS/NAC/SIL Change, Mode A Code Change

	Time Between 2 Transmissions (seconds)	**Average Number per Second**	**Peak Number per Second**	**Number over 60 Seconds**	**Comment**
Airborne Position Message	0.5	2	2	120	
Airborne Velocity Message	0.5	2	2	120	
Aircraft Identification	5	0.2	1	12	
Target State and Status	1.25	0.8	-	-	
Aircraft Operational Status	2.5	0.4	2	14	for 36s
	0.8	1.25		30	for 24s after a TCAS/NAC/ SIL change
Aircraft Status	5	0.2	2	7	for 36s
	0.8	1.25		30	for 24s after Mode A Code change
Total number over the period			9	333	
Average /second				5.55	

R.3.6 Scenario 6: On-the-Ground, Moving, Mode A Code Change, NIC_{SUPP}/NAC/SIL Change

Conditions:

- On-the-Ground
- Moving
- Change in Mode A Code
- Change in the status of one or more of NIC_{SUPP}/NAC/SIL

Table R-6: On-the-Ground, Moving, Mode A Code Change, NIC_{SUPP}/NAC/SIL Change

	Time Between 2 Transmissions (seconds)	Average Number per Second	Peak Number per Second	Number over 60 Seconds	Comment
Surface Position Message	0.5	2	2	120	
Aircraft Identification	5	0.2	1	12	
Aircraft Operational Status	2.5	0.4	2	14	for 36s
	0.8	1.25		30	for 24s after a NIC/NAC/SIL change
Aircraft Status	5	0.2	2	7	for 36s
	0.8	1.25		30	for 24s after Mode A Code change
Total number over the period			7	213	
Average /second				3.55	