UAT-WP-12-07
8 April 2002

RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #12

Draft #12 of Section 2.2 for Review in Washington

Presented by Chris Moody and Gary Furr

SUMMARY
This is Draft #12 of Section 2.2 of the UAT MOPS for review at the meeting in Washington DC.

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Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance Broadcast (ADS-B)

Section 2.2
Draft 12 (L)
Edited during and after the 25 March Telecon and on 26 and 28 March by Chris and between 29 March and 3 April by Gary

Updated: Month day, 2002
RTCA/DO-???
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Foreword

This report was prepared by Special Committee 186 (SC-186) and approved by the RTCA Program Management Committee (PMC) on MONTH xx, 2002.

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

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1.0 Purpose And Scope

2.0 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.2 Equipment Performance – Standard Conditions

2.2.1 Definition of Standard Conditions

2.2.1.1 Signal Levels

Unless otherwise noted, the signal levels specified for transmitting devices in this subsection exist at the antenna end of an equipment-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-equipment 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.*

2.2.1.2 Desired Signals

Unless otherwise specified, the desired signal specified as part of receiver performance requirements is any valid ADS-B Long Type message.

2.2.2 ADS-B Transmitter Characteristics

2.2.2.1 Transmission Frequency

The transmission frequency f_0 **shall** be 978 MHz, +/- 20 PPM.

Note: *All transmissions from ground stations will operate at the same transmission frequency and frequency tolerance.*

2.2.2.2 Modulation Rate

The nominal modulation rate is 1.041667 megabits per second.

Notes:

1. *Each bit period = 0.96 microsecond.*
2. *Ground Uplink Messages will use the same modulation type.*
3. *Adherence to this rate is assured as part of the requirement of Section 2.2.2.4.*

2.2.2.3 Modulation Type

Data **shall** be modulated onto the carrier using binary Continuous Phase Frequency Shift Keying. The modulation index, *h*, **shall** be 0.6; this implies that if the data rate is R_b, then the nominal frequency separation between "mark" (binary 1) and "space" (binary 0) is $\Delta f = h \bullet R_b$. A binary 1 **shall** be indicated by a shift up in frequency from the nominal carrier frequency of $\Delta f/2$ (+312.5 kHz) and a binary 0 by a shift of $-\Delta f/2$ (-312.5 kHz). These frequency deviations apply at the optimum sampling points for the bit interval.

<u>Notes:</u>

1. *Filtration of the transmitted signal (at base band and/or after frequency modulation), will be required to meet the spectral containment requirement of subparagraph 2.2.2.5. This filtration will cause the deviation to exceed these values at points other than the optimum sampling points.*

2. *The optimum sampling point of a received bit stream is at the nominal center of each bit period, when the frequency offset is either plus or minus 312.5 kHz.*

3. *Due to filtering of the transmitted signal, the received frequency offset varies continuously between the nominal values of ±312.5 kHz (and beyond), and the optimal sampling point may not be easily identified. This point can be defined in terms of the so-called "eye diagram" of the received signal. The eye diagram is a superposition of samples of the post-detection waveform shifted by multiples of the bit period (0.96 microsecond). The optimum sampling point is the point during the bit period at which the opening of the eye diagram (i.e., the minimum separation between positive and negative frequency offsets at very high signal-to-noise ratios) is maximized.*

2.2.2.4 Modulation Distortion

The minimum opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) **shall** be no less than 560 kHz when measured over an entire Long ADS-B message containing pseudorandom payload data.

2.2.2.5 Transmitter Power Output

The Time/Amplitude profile of an ADS-B Message Transmission **shall** fall within the following limits relative to a *reference time* defined as 0.48 microseconds prior to the center of the first bit of the synchronization sequence (subparagraph 2.2.3.1.1) appearing at the output port of the equipment.

All power measurements for subparagraphs **a** and **f** assumes a 300 kHz bandwidth. All power measurements for subparagraphs **b**, **c**, **d** and **e** assumes a 2 MHz bandwidth.

a. Prior to 8 bit periods before the reference time, the average RF output power **shall** not exceed –80 dBm.

<u>Note:</u> *This unwanted power requirement is necessary to ensure that the ADS-B transmitter does not prevent closely located UAT receiving equipment from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment exceeds 20 dB.*

b. Between 8 and 4 bit periods prior to the reference time, the RF output power **shall** remain at least 20 dB below the minimum power requirement for the appropriate equipment class per Table 2.1.11.

c. During the Active state, defined as beginning at the reference time and continuing for the duration of the message (276 bit periods for the Basic Message and 420 bit periods for the Long Message), the RF output power **shall** comply with Table 2.1.12.

d. The RF output power **shall** not exceed the maximum limits of Table 2.1.12 at any time during the ADS-B Message Transmission.

e. Within 4 bit periods after the end of the Active state, the RF output power **shall** be at a level at least 20 dB below the minimum power requirement for the appropriate equipment class per Table 2.1.11.

f. Within 8 bit periods after the end of the Active state, the average RF output power **shall** fall to a level not to exceed –80 dBm.

Note: *This unwanted power requirement is necessary to ensure that the ADS-B transmitter does not prevent closely located UAT receiving equipment from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment exceeds 20 dB.*

These requirements are depicted graphically in Figure 2.2.2.5.

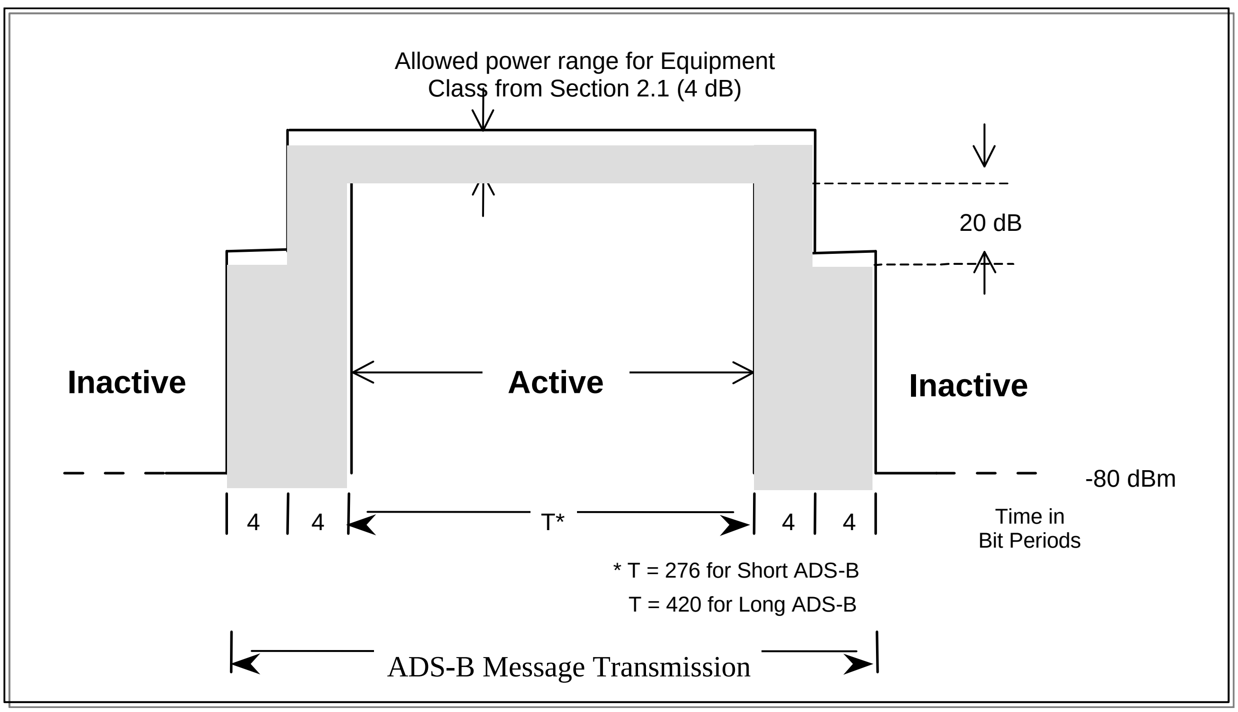

Figure 2.2.2.5: Time/Amplitude Profile of ADS-B Message Transmission

2.2.2.6 In Band Transmission Spectrum

The average spectrum of a UAT message transmission modulated with pseudo-random payload data **shall** fall within the limits specified in Table 2.2.2.6 and Figure 2.2.2.6 when measured in a 100 kHz bandwidth.

Table 2.2.2.6: UAT Transmit Spectrum

Frequency Offset From Center	**Required Attenuation from Maximum (dB)**
All frequencies in the range 0 – 0.5 MHz	0
All frequencies in the range 0.5 – 1.0 MHz	Based on linear* interpolation between these points
1.0 MHz	18
All frequencies in the range 1.0 – 2.25 MHz	Based on linear* interpolation between these points
2.25 MHz	50
All frequencies in the range 2.25 – 3.25 MHz	Based on linear* interpolation between these points
3.25	60

** based on amplitude in dB and a linear frequency scale*

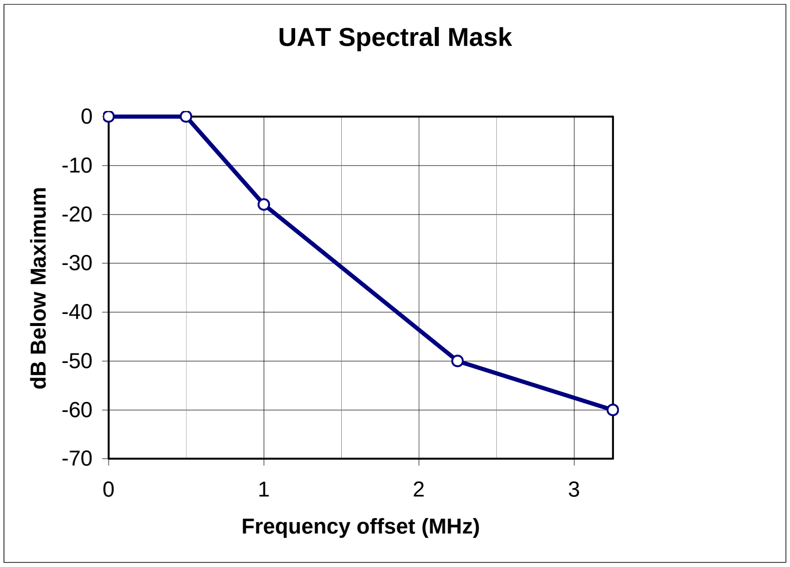

Figure 2.2.2.6: UAT Transmit Spectrum

Note: *This requirement extends to 250% of the "occupied bandwidth," where the occupied bandwidth has been determined to be 1.3 MHz. Reference 47 CFR, Part 2.1.*

2.2.2.7 Out-of-Band Emissions

Out-of-Band emissions **shall** comply with applicable FCC regulations beyond 250% of the authorized bandwidth, that is, 3.25 MHz from the center frequency. Reference 47 CFR, Part 87.139.

2.2.3 Broadcast Message Characteristics

Subparagraphs 2.2.3.1 through 2.2.3.2.4 define the format for the ADS-B and the Ground Uplink message types. Each of these messages types will normally occur in separate portions of the UAT frame as described in Section 1.

2.2.3.1 ADS-B Message Format

The ADS-B Message format is shown in Figure 2.2.3.1. Each message element is described in detail in subparagraphs 2.2.3.1.1 through 2.2.3.2.3.

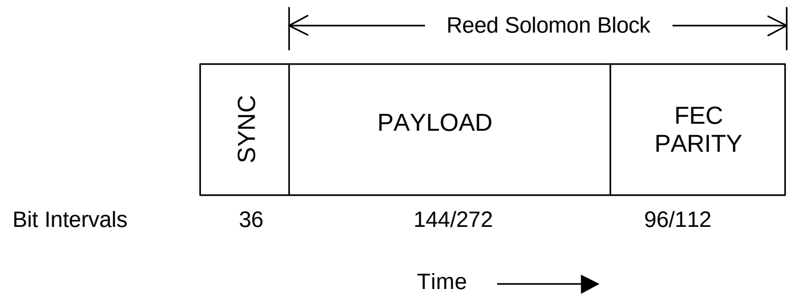

Figure 2.2.3.1: ADS-B Message Format

Notes:

1. *All bit intervals depicted in Figure 2.2.3.1 comprise the ACTIVE state of the transmitter as defined in subparagraph 2.2.2.5.c.*

2. *Traffic Information Services-Broadcast (TIS-B) transmissions use the ADS-B message format — including use of the same synchronization pattern. Therefore, there is actually no need for a "TIS-B message" and none is referred to in this MOPS.*

2.2.3.1.1 Synchronization

Following ramp up, the message **shall** include a 36-bit synchronization sequence. For the ADS-B messages the sequence **shall** be:

111010101100110111011010010011100010

with the left-most bit transmitted first.

2.2.3.1.2 Payload

The format, encoding and transmission order of the payload message element is defined in subparagraph 2.2.4.

2.2.3.1.3 FEC Parity

2.2.3.1.3.1 Code Type

The FEC Parity generation **shall** be based on a systematic Reed-Solomon (RS) 256-ary code with 8-bit code word symbols. FEC Parity generation **shall** be per the following code:

a. Basic ADS-B message: Parity **shall** be per a RS (30, 18) code.

Note: *This results in 12 bytes (code symbols) of parity capable of correcting up to 6 symbol errors per block.*

b. Long ADS-B message: This **shall** be per a RS (48, 34) code.

Note: *This results in 14 bytes (code symbols) of parity capable of correcting up to 7 symbol errors per block.*

For either message length the primitive polynomial of the code **shall** be as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1 .$$

The generator polynomial **shall** be as follows:

$$\prod_{i=120}^{P} (x - a^i) .$$

P = 131 for RS (30,18) code and P = 133 for RS(48,34) code

a is a primitive element of a Galois field of size 256 (i.e., GF(256)).

Note: *See Appendix C for more information on the implementation of the Reed Solomon code.*

2.2.3.1.3.2 Generation and Transmission Order of FEC Parity

FEC Parity bytes **shall** be ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte **shall** be most significant to least significant. FEC Parity bytes **shall** follow the message payload.

Note: *See Appendix C for a message generation and encoding example.*

2.2.3.2 Ground Uplink Message Format

The Ground Uplink message format is shown in Figure 2.2.3.2. Each message element is described in detail in subparagraphs 2.2.3.2.1 through 2.2.3.2.4.

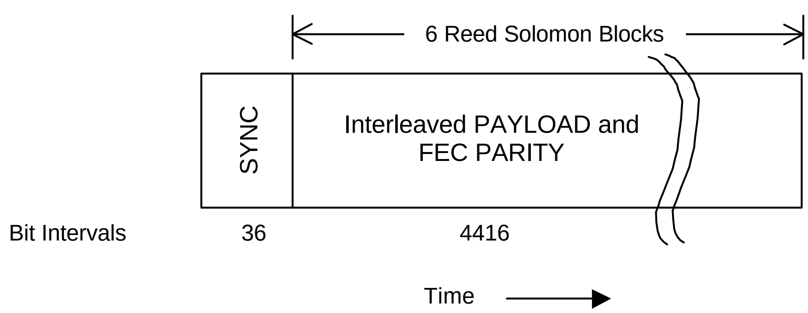

Figure 2.2.3.2: Ground Uplink Message Format

2.2.3.2.1 Synchronization

The polarity of the bits of the synchronization sequence is inverted from that used for the ADS-B message, that is, the ONEs and ZEROs are interchanged. This synchronization sequence is:

000101010011001000100101101100011101

with the left-most bit transmitted first.

Note: *Because of the close relationship between the synchronization sequences used for the ADS-B and Ground Uplink Messages, the same correlator can search for both simultaneously.*

2.2.3.2.2 Payload (Before Interleaving and After De-interleaving)

The Payload consists of two components: the first eight bytes that comprise UAT-Specific Header and bytes 9 through 432 that comprise the Application Data as shown in Table 2.2.3.2.2. Bytes and bits are fed to the interleaving process with the most significant byte of byte #1, transmitted first, and within each byte, the most significant bit, bit #1, transmitted first.

<u>Table 2.2.3.2.2:</u> Format of the Ground Uplink Message Payload

Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1	(MSB)							
2	Ground Station Latitude (WGS-84)							
3							(LSB)	(MSB)
4								
5	Ground Station Longitude (WGS-84)							
6							(LSB)	P Valid
7	UTC Coupled	Reserved	App Data Valid	(MSB)		Slot ID		(LSB)
8	(MSB)	TIS-B Site ID		(LSB)	Reserved			
9	Application Data							
432								

2.2.3.2.2.1 UAT-Specific Header

2.2.3.2.2.1.1 "GROUND STATION LATITUDE" Field Encoding

The "GROUND STATION LATITUDE" field is a 23-bit (bit 1 of byte 1 through bit 7 of byte 3) field used to identify the latitude of the ground station. The encoding of this field by the ground station will be the same as defined for latitude information in the ADS-B message (see subparagraph 2.2.4.5.2.1).

2.2.3.2.2.1.2 "GROUND STATION LONGITUDE" Field Encoding

The "GROUND STATION LONGITUDE" field is a 24-bit (bit 8 of byte 3 through bit 7 of byte 6) field used to identify the longitude of the ground station. The encoding of this field by the ground station will be the same as defined for longitude information in the ADS-B message (see subparagraph 2.2.4.5.2.1).

2.2.3.2.2.1.3 "POSITION VALID" Field Encoding

The "POSITION VALID" field is a 1-bit (bit 8 of byte 6) field used to indicate whether or not the position in the header is valid. An encoding of ONE represents a VALID position. An encoding of ZERO represents an INVALID position.

2.2.3.2.2.1.4 "UTC" Field Encoding

The "UTC" field is a 1-bit (bit 1 of byte 7) field used to indicate whether or not the ground station 1 Pulse Per Second timing is valid. An encoding of ONE represents VALID timing. An encoding of ZERO represents INVALID timing.

2.2.3.2.2.1.5 Reserved Bit

Bit 2 of byte 7 is reserved for future use and will always be set to ZERO.

2.2.3.2.2.1.6 "APPLICATION DATA VALID" Field Encoding

The "APPLICATION DATA VALID" field is a 1-bit (bit 3 of byte 7) field used to indicate whether or not the Application Data is valid for operational use. An encoding of ONE represents VALID Application Data. An encoding of ZERO represents INVALID Application Data.

Notes:

1. *Airborne applications should ignore the Application Data field when this bit is set to INVALID.*
2. *This field will allow testing and demonstration of new products without impact to operational airborne systems.*

2.2.3.2.2.1.7 "SLOT ID" Field Encoding

The "SLOT ID" field is a 5-bit (bit 4 through bit 8 of byte 7) field used to identify the time slot within which the Ground Uplink message transmission took place. This field is encoded as a 5-bit unsigned binary numeral.

Note: *The Slot for certain ground station messages may be continually shifted for maximum interference tolerance to other users sharing the band. Airborne receivers do not need a priori knowledge of this shifting scheme; this is for ground service providers to coordinate. The actual Slot ID in use for each uplink message will always be properly encoded by the ground station.*

2.2.3.2.2.1.8 "TIS-B SITE ID" Field Encoding

The "TIS-B SITE ID" field is a 4-bit (bits 1, through 4 of byte 8) field used to convey the reusable TIS-B Site ID that is also encoded with each TIS-B transmission as shown in Table 2.2.3.2.2.1.8 below:

Table 2.2.3.2.2.1.8: Encoding of TIS-B Site ID

Encoding	Meaning
0000	No TIS-B information transmitted from this site
0001	Assigned to ground stations that provide TIS-B information by TIS-B administration authority
through	
1111	

Note: *This field supports TIS-B applications that verify TIS-B transmissions were transmitted from the site located at the Latitude/Longitude encoded in the UAT-Specific Header portion of the Ground Uplink payload.*

2.2.3.2.2.1.9 Reserved Bits

Bits 5 through 8 of byte 8 are reserved for future use and will be set to ALL ZEROs.

2.2.3.2.2.2 Ground Uplink Application Data

Definition of the Application Data field is beyond the scope of this MOPS document and will be provided by other documents.

2.2.3.2.3 FEC Parity (Before Interleaving and After De-interleaving)

2.2.3.2.3.1 Code Type

The FEC Parity generation is based on a systematic RS 256-ary code with 8 bit code word symbols. FEC Parity generation for each of the six blocks is per RS (92,72) code.

Note: *This results in 20 bytes (symbols) of parity capable of correcting up to 10 symbol errors per block. The additional use of interleaving for the Ground Uplink message allows additional robustness against concentrated burst errors.*

The primitive polynomial of the code is as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1.$$

The generator polynomial is as follows:

$$\prod_{i=120}^{P} (x - a^i).$$

Where P = 139

a is a primitive element of a Galois field of size 256 (i.e., GF(256)).

Note*:* *See Appendix C for more information on Reed Solomon encoding.*

2.2.3.2.3.2 Generation and Transmission Order of FEC Parity

FEC Parity bytes are ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte will be most significant to least significant. FEC Parity bytes will follow the message payload.

Note*:* *See Appendix C for a message generation and encoding example. Even though the example is for an ADS-B message, the procedure applies to any Reed Solomon block being encoded/decoded.*

2.2.3.2.4 Interleaved Payload and FEC Parity

Ground Uplink Messages are interleaved and transmitted by the Ground Station, as listed below:

a. Interleaving Procedure: The part of the burst labeled "Interleaved Payload and FEC Parity" in Figure 2.2.3.2 consists of 6 interleaved Reed-Solomon blocks. The interleaver is represented by a 6 by 92 matrix, where each entry is a RS 8-bit symbol. Each row comprises a single RS (92,72) block as shown in Table 2.2.3.2.4. In Table 2.2.3.2.4, Block numbers prior to interleaving are represented as "A" through "F." The information is ordered for transmission column by column, starting at the upper left corner of the matrix.

Table 2.2.3.2.4: Ground Uplink Interleaver Matrix

RS Block	Payload Byte # (From subparagraph 2.2.3.2)						FEC Parity (Block /Byte #)			
A	1	2	3	…	71	72	A/1	…	A/19	A/20
B	73	74	75	…	143	144	B/1	…	B/19	B/20
C	145	146	147	…	215	216	C/1	…	C/19	C/20
D	217	218	219	…	287	288	D/1	…	D/19	D/20
E	289	290	291	…	359	360	E/1	…	E/19	E/20
F	361	362	363	…	431	432	F/1	…	F/19	F/20

Note: *In Figure 2.2.3.2.4, Payload Byte #1 through #72 are the 72 bytes (8 bits each) of payload information carried in the first RS (92,72) block. FEC Parity A/1 through A/20 are the 20 bytes of FEC parity associated with that block (A).*

b. Transmission Order: The bytes are then transmitted in the following order:

1,73,145,217,289,361,2,74,146,218,290,362,3,. . .,C/20,D/20,E/20,F/20.

Note: *On reception these bytes must be de-interleaved so that the RS blocks can be reassembled prior to error correction decoding.*

2.2.4 The ADS-B Message Payload

2.2.4.1 Payload Type

Each transmitted ADS-B message contains a payload that the receiver first identifies by the "PAYLOAD TYPE CODE" encoded in the first 5 bits of the payload. The Payload Type Code allows the receiver to interpret the contents of the ADS-B message payload per the definition contained in subparagraphs 2.2.4.2 through 2.2.4.5.8.

2.2.4.2 Payload Elements

For convenience, ADS-B message payload is organized into *payload elements*. These elements contain the individual message *fields* (e.g., LATITUDE, ALTITUDE, etc) that correspond to the various report elements issued by an ADS-B receiver to an application system as defined in the ADS-B MASPS, RTCA Document DO-242. Payload elements and their lengths are shown in Table 2.2.4.2.

Table 2.2.4.2: ADS-B Payload Elements

Payload Element	Payload Bytes	Applicable DO-242 Reports	Subparagraph References
HEADER (HDR)	4	All	2.2.4.5.1
STATE VECTOR (SV)	13	State Vector	2.2.4.5.2
MODE STATUS (MS)	12	Mode Status	2.2.4.5.4
AUX. STATE VECTOR (AUX SV)	5	State Vector, Air Reference Vector	2.2.4.5.5
TARGET STATE (TS)	5	Target State	2.2.4.5.6 2.2.4.5.7
TRAJECTORY CHANGE +0 (TCR+0)	12	Trajectory Change	2.2.4.5.8
TRAJECTORY CHANGE +1 (TCR+1)	12	Trajectory Change	2.2.4.5.8

2.2.4.3 ADS-B Payload Composition by Payload Type Code

Table 2.2.4.3 provides the assignment of payload elements to each payload type code.

Table 2.2.4.3: Composition of ADS-B Payload

Payload Type Code	ADS-B Message Payload Byte Number							
	1 ---- 4	5 ---- 17	18 --------- 24		25 ---- 28	29	30 --- 33	34
0 *(Note 1)*	HDR	SV	*Res*	*Byte 19-34 Not present in Type 0*				
1	HDR	SV	MS				AUX SV	
2	HDR	SV	*Reserved (Note 2)*				AUX SV	
3	HDR	SV	MS				TS	*Res*
4	HDR	SV	*Reserved for TC+0 (Note 2)*				TS	*Res*
5	HDR	SV	*Reserved for TC+1 (Note 2)*				AUX SV	
6	HDR	SV	*Res. (Note 2)*		TS	*Res*	AUX SV	
7	HDR	SV	*Reserved (Note 3)*					
8	HDR	SV						
9	HDR	SV						
10	HDR	SV						
11 through 29	HDR	*Reserved (Note 2)*						
30, 31	HDR	Reserved for Developmental Use (*Note 4)*						

Notes:

1. *Payload Type 0 is conveyed in the Basic ADS-B message; byte 18 is reserved for future definition.*

2. *Not defined in this MOPS. Reserved for definition in future versions.*

3. *Payload Types 7 – 10 are defined to allow a degree of backward compatibility with future message definition for receivers operating according to this MOPS.*

4. *Payload Types 30 and 31 are intended for developmental use, such as to support on-air flight testing of new payload types, prior to their adoption in future MOPS versions. These payload types should be ignored by MOPS compliant equipment.*

2.2.4.4 Payload Transmission Order

The ADS-B message payload **shall** be transmitted in byte order with byte #1 first. Within each byte, bits **shall** be transmitted in order with bit #1 transmitted first. Bit-level definition of the payload is provided in subparagraphs 2.2.4.5 through 2.2.4.5.8.

2.2.4.5 Payload Contents

2.2.4.5.1 HEADER Element

Format for the HEADER element is defined in Table 2.2.4.5.1. This encoding **shall** apply to ADS-B messages with PAYLOAD TYPE CODES of "0" through "10". Each of the fields shown is defined in subparagraphs 2.2.4.5.1.1 through 2.2.4.5.1.3.6.

Table 2.2.4.5.1: Encoding of HEADER Element into ADS-B Payload

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1	(MSB)		Payload Type Code		(LSB)	Address Qualifier		
2	(MSB) A1	A2	A3	. . .				
3					Address			
4					. . .	A22	A23	A24 (LSB)

.

.

2.2.4.5.1.1 "PAYLOAD TYPE CODE" Field Encoding

The "PAYLOAD TYPE CODE" field is a 5-bit (bit 1 of byte 1 through bit 5 of byte 1) field used to identify the payload for decoding by the receiver. Definition of the "PAYLOAD TYPE CODE" field encoding that **shall** be used for all ADS-B messages is provided in Table 2.2.4.3.

2.2.4.5.1.2 "ADDRESS QUALIFIER" Field Encoding

The "ADDRESS QUALIFIER" field is a 3-bit (bit 6 of byte 1 through bit 8 of byte 1) field used to indicate what the 24-bit "ADDRESS" field represents. Definition of the "ADDRESS QUALIFIER" field encoding that **shall** be used for all ADS-B messages is provided in Table 2.2.4.5.1.2.

Table 2.2.4.5.1.2: "ADDRESS QUALIFIER" Encoding

Address Qualifier (binary)			Address Qualifier (decimal)	Address Type	Reference subparagraph
Bit 6	Bit 7	Bit 8			
0	0	0	0	Ownship ICAO 24-bit aircraft address	2.2.4.5.1.3.1
0	0	1	1	Ownship self-assigned temporary address	2.2.4.5.1.3.2
0	1	0	2	ICAO 24-bit aircraft address of TIS-B target.	2.2.4.5.1.3.3
0	1	1	3	TIS-B track file identifier for TIS-B target	2.2.4.5.1.3.4
1	0	0	4	Surface Vehicle	2.2.4.5.1.3.5
1	0	1	5	Fixed ADS-B Beacon	2.2.4.5.1.3.6
1	1	0	6	(Reserved)	
1	1	1	7	(Reserved)	

2.2.4.5.1.3 "ADDRESS" Field Encoding

The "ADDRESS" field is a 24-bit (bit 1 of byte 2 through bit 8 of byte 4) field used in conjunction with the "ADDRESS QUALIFIER" field to provide a convenient way to correlate various ADS-B messages from the same A/V. The meaning of the "ADDRESS" field depends on the "ADDRESS QUALIFIER" field as described in subparagraphs 2.2.4.5.1.3.1 through 2.2.4.5.1.3.6.

2.2.4.5.1.3.1 ICAO 24-bit Aircraft Address of Transmitting Aircraft

An "ADDRESS QUALIFIER" value of "0" **shall** indicate that message is an ADS-B message from an aircraft, and that the "ADDRESS" field holds the ICAO 24-bit address that has been assigned to that particular aircraft. The ICAO Aircraft Address **shall** be stored (or "latched") in the UAT Transmitting System upon Power Up.

If the Address Selection Input becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, the "ADDRESS QUALIFIER" **shall** default to a value of ALL ZEROs.

Note: *The world-wide method for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9].*

2.2.4.5.1.3.2 Self-Assigned Temporary Address of Transmitting Aircraft

An "ADDRESS QUALIFIER" value of "1" **shall** indicate that the message is an ADS-B message from an aircraft, and that the "ADDRESS" field holds the transmitting aircraft's self-assigned own-ship temporary address.

If the Address Selection Input becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, the "ADDRESS QUALIFIER" **shall** default to a value of ALL ZEROs.

The self-assigned temporary address **shall** be generated as follows:

Let: $ADDR_P$ = the ICAO 24-bit address that has been assigned to the aircraft;

$ADDR_T$ = the temporary address that is to be generated;

M(1) = the 12 least significant bits (LSBs) of the own-ship "LATITUDE" field (per subparagraph 2.2.4.5.2.1) at the time the temporary address option is selected;

M(2) = the 12 least significant bits (LSBs) of the own-ship "LONGITUDE" field (per subparagraph 2.2.4.5.2.1) at the time the temporary address option is selected;

M(3) = $4096 \times M(1) + M(2)$; and

TIME = the number of seconds that have elapsed since UTC midnight at the time the temporary address option is selected, represented as a 24-bit number.

Also, let "⊕" denote the modulo 2 bit-by-bit addition (or "exclusive OR") operation.

a. If the transmitting aircraft's ICAO 24-bit address $ADDR_P$ is available, then the temporary address $ADDR_T$ **shall** be the modulo 2, bit-by-bit summation of the permanent address and M(3), that is:

$$ADDR_T = ADDR_P \oplus M(3).$$

b. If the aircraft's 24-bit ICAO address $ADDR_P$ is not available, then time of day **shall** be used as an additional randomizer. In that case, the temporary address $ADDR_T$ **shall** be the modulo 2, bit-by-bit summation of TIME and M(3), that is,

$$ADDR_T = TIME \oplus M(3).$$

2.2.4.5.1.3.3 ICAO 24-bit Aircraft Address of TIS-B Target Aircraft

An "ADDRESS QUALIFIER" value of "2" is used to indicate that the message is a TIS-B transmission and the "ADDRESS" field holds the ICAO 24-bit address that has been assigned to the target aircraft being described in the message.

Note: *The world-wide scheme for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9]*

2.2.4.5.1.3.4 TIS-B Track File Identifier

An "ADDRESS QUALIFIER" value "3" is used to indicate that the message is a TIS-B transmission and that the "ADDRESS" field holds a TIS-B track file identifier by which the TIS-B data source identifies the target aircraft being described in the message.

Note: *It is beyond the scope of this MOPS to specify the method by which a TIS-B service provider would assign track file identifiers for those TIS-B targets for which the ICAO 24-bit address is unknown.*

2.2.4.5.1.3.5 Surface Vehicle Address

An "ADDRESS QUALIFIER" value of "4" is used to indicate that the "ADDRESS" field holds the address of a surface vehicle authorized to operate in the airport's surface movement area.

Note: *It is beyond the scope of this MOPS to specify the method by which ADS-B surface vehicle addresses are assigned.*

2.2.4.5.1.3.6 Fixed ADS-B Beacon Address

An "ADDRESS QUALIFIER" value of "5" is used to indicate that the "ADDRESS" field holds the address assigned to a fixed ADS-B beacon or "parrot."

Note: *It is beyond the scope of this MOPS to specify the method by which ADS-B beacon addresses are assigned.*

2.2.4.5.2 STATE VECTOR Element

Format for the STATE VECTOR element is defined in Table 2.2.4.5.2. This encoding **shall** apply to ADS-B messages with PAYLOAD TYPE CODES of "0" through "10," when the ADDRESS QUALIFIER value is "0," "1," "4" or "5." Each of the fields shown is defined in subparagraphs 2.2.4.5.2.1 through 2.2.4.5.2.10.

Table 2.2.4.5.2: Format of STATE VECTOR Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
. . .								
5	(MSB)							
6				**Latitude (WGS-84)**				
7							(LSB)	(MSB)
8								
9				**Longitude (WGS-84)**				
10							(LSB)	**Alt Type**
11	(MSB)			**Altitude**				
12				(LSB)	(MSB)	**NIC**		(LSB)
13	**(MSB)**	**A/G State**	**(LSB)**					
14				**Horizontal Velocity**				
15								
16				**Vertical Velocity or Aircraft Length/Width Code**				
17					**UTC**		**Reserved**	
. .								

2.2.4.5.2.1 "LATITUDE" and "LONGITUDE" Field Encoding

a. The "LATITUDE" field is a 23-bit (bit 1 of byte 5 through bit 7 of byte 7) field used to encode the latitude of the ADS-B transmitter in WGS-84. The encoding of this field **shall** be as indicated in Table 2.2.4.5.2.1. Also see Figure 2.2.4.5.2.1.

b. The "LONGITUDE" field is a 24-bit (bit 8 of byte 7 through bit 7 of byte 10) field used to encode the latitude of the ADS-B transmitter in WGS-84. The encoding of this field **shall** be as indicated in Table 2.2.4.5.2.1. Also see Figure 2.2.4.5.2.1.

c. The encoding of ALL ZEROs in the "LATITUDE" <u>and</u> "LONGITUDE" <u>and</u> "NIC" (subparagraph 2.2.4.5.2.4) fields **shall** indicate that Latitude/Longitude information is "unavailable."

<u>Note</u>*: Since the encoding of ALL ZEROs is a valid location on the earth, ADS-B receiving systems will interpret this as Latitude/Longitude information "unavailable" only if the NIC field is also set to ZERO.*

<u>Table 2.2.4.5.2.1:</u> Angular Weighted Binary Encoding of Latitude and Longitude.

Quadrant	**"LATITUDE" or "LONGITUDE" bits**		**Meaning** $LSB = \frac{360}{2^{24}} = 0.00002146°$	
	MSB	LSB	**Latitude**	**Longitude**
	0000 0000 0000 0000 0000 0000		ZERO degrees (Equator)	ZERO degrees (Prime Meridian)
1st	0000 0000 0000 0000 0000 0001		*LSB* degrees North	*LSB* degrees East
quadrant	…		…	…
	0011 1111 1111 1111 1111 1111		(90-*LSB*) degrees North	(90-*LSB*) degrees East
	0100 0000 0000 0000 0000 0000		90 degrees (North Pole)	90 degrees East
2nd	0100 0000 0000 0000 0000 0001		<Illegal Values>	(90+*LSB*) degrees East
quadrant	…		<Illegal Values>	…
	0111 1111 1111 1111 1111 1111		<Illegal Value>	(180-*LSB*) degrees East
	1000 0000 0000 0000 0000 0000		<Illegal Value>	180 degrees East or West
3rd	1000 0000 0000 0000 0000 0001		<Illegal Value>	(180-*LSB*) degrees West
quadrant	…		<Illegal Values>	…
	1011 1111 1111 1111 1111 1111		<Illegal Values>	(90-LSB) degrees West
	1100 0000 0000 0000 0000 0000		-90 degrees (South Pole)	90 degrees West
4th	1100 0000 0000 0000 0000 0001		(90-*LSB*) degrees Sourth	(90-*LSB*) degrees West
quadrant	…		…	…
	1111 1111 1111 1111 1111 1111		*LSB* degrees South	*LSB* degrees West

<u>Notes</u>:

1. *The most significant bit (MSB) of the angular weighted binary "LATITUDE" is omitted from the transmitted message. This is because all valid Latitudes, other than the Latitude of the North pole (exactly 90 degrees North), have the same value in their 2 most significant bits.*

2. *Raw data used to establish the Latitude or Longitude fields will normally have more resolution (i.e., more bits) than that required by the Latitude or Longitude fields. When converting such data to the Latitude or Longitude subfields, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the Latitude or Longitude field.*

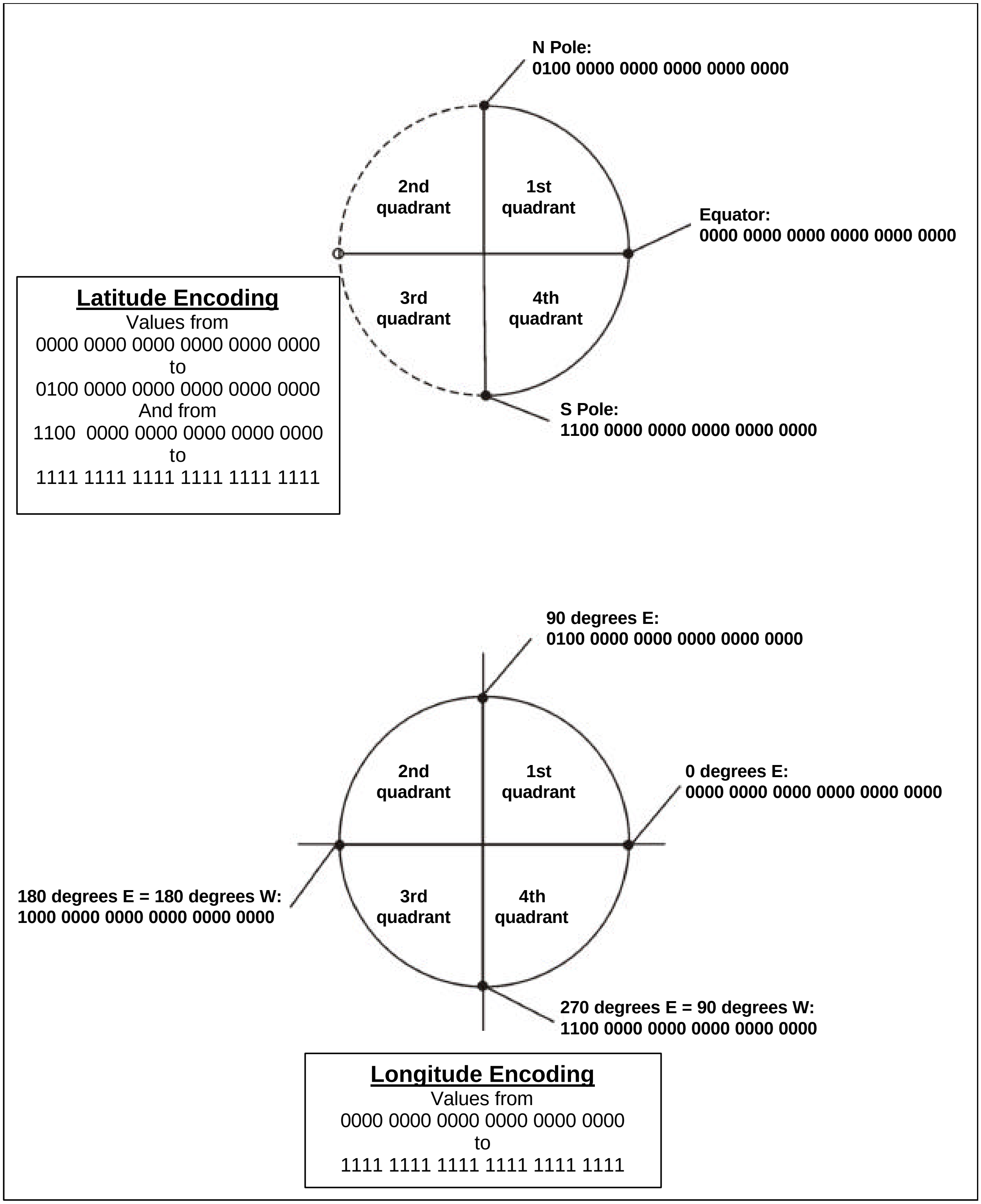

Figure 2.2.4.5.2.1: Angular Weighted Binary Encoding of Latitude and Longitude.

2.2.4.5.2.2 "ALTITUDE TYPE" Field Encoding

The "ALTITUDE TYPE" field is a 1-bit (bit 8 of byte 10) field used to identify the source of information in the "ALTITUDE" field. The encoding of this field is reflected in Table 2.2.4.5.2.2.

If the Altitude Type Selection Input becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, the "ALTITUDE TYPE" **shall** default to a value of ZERO.

Table 2.2.4.5.2.2: "ALTITUDE TYPE" Encoding

Altitude Type	**"ALTITUDE" Field** (Subparagraph 2.2.4.5.2.3)	**"SECONDARY ALTITUDE" Field** (Subparagraph 2.2.4.5.5.1)
0	Pressure Altitude	Geometric Altitude
1	Geometric Altitude	Pressure Altitude

Note: *"Pressure Altitude" refers to "Barometric Pressure Altitude" relative to a standard pressure of 1013.2 millibars (29.92 in Hg) and specifically* ***DOES NOT*** *refer to "Barometric Corrected Altitude."*

A means **shall** be provided to operationally select the ALTITUDE TYPE that is reported.

2.2.4.5.2.3 "ALTITUDE" Field Encoding

The "ALTITUDE" field is a 12-bit (bit 1 of byte 11 through bit 4 of byte 12) field used to encode the altitude of the ADS-B transmitter. The encoding of this field **shall** be as indicated in Table 2.2.4.5.2.3.

Table 2.2.4.5.2.3: "ALTITUDE" Encoding

Coding (binary) MSB LSB	**Coding** (decimal)	**Meaning**
0000 0000 0000	0	Altitude information unavailable
0000 0000 0001	1	Altitude = -1000 feet
0000 0000 0010	2	Altitude = -975 feet
…	…	…
0000 0010 1000	40	Altitude = -25 feet
0000 0010 1001	41	Altitude = ZERO feet
0000 0010 1010	42	Altitude = 25 feet
…	…	…
1111 1111 1110	4094	Altitude = 101,325 feet
1111 1111 1111	4095	Altitude > 101,337.5 feet

Note: *Raw data used to establish the "ALTITUDE" field will normally have more resolution (i.e., more bits) than that required by the "ALTITUDE" field. When converting such data to the "ALTITUDE" field, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "ALTITUDE" field.*

2.2.4.5.2.4 "NIC" Field Encoding

The Navigation Integrity Categories ("NIC") field is a 4-bit (bits 5, through 8, of byte 12) field used to allow surveillance applications to determine whether the reported position has an acceptable level of integrity for the intended use. The value of the NIC parameter specifies an integrity containment radius, R_C. The encoding of this field **shall** be as indicated in Table 2.2.4.5.2.4.

If the NIC Input becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, the "NIC" **shall** default to a value of ALL ZEROs.

<u>Table 2.2.4.5.2.4:</u> "NIC" Encoding

NIC binary (MSB … LSB)	NIC (decimal)	Horizontal and Vertical Containment Bounds	Comment
0000	0	$R_C \geq$ 37.04 km (20 NM)	Unknown Integrity
0001	1	$R_C <$ 37.04 km (20 NM)	RNP-10 containment radius
0010	2	$R_C <$ 14.816 km (8 NM)	RNP-4 containment radius
0011	3	$R_C <$ 7.408 km (4 NM)	RNP-2 containment radius
0100	4	$R_C <$ 3.704 km (2 NM)	RNP-1 containment radius
0101	5	$R_C <$ 1852 m (1 NM)	RNP-0.5 containment radius
0110	6	$R_C <$ 1111.2 m (0.6 NM)	RNP-0.3 containment radius
0111	7	$R_C <$ 370.4 m (0.2 NM)	RNP-0.1 containment radius
1000	8	$R_C <$ 185.2 m (0.1 NM)	RNP-0.05 containment radius
1001	9	$R_C <$ 75 m and VPL < 112 m	e.g., WAAS HPL, VPL
1010	10	$R_C <$ 25 m and VPL < 37.5 m	e.g., WAAS HPL, VPL
1011	11	$R_C <$ 7.5 m and VPL < 11 m	e.g., LAAS HPL, VPL
1100	12	(Reserved)	(Reserved)
1101	13	(Reserved)	(Reserved)
1110	14	(Reserved)	(Reserved)
1111	15	(Reserved)	(Reserved)

***<u>Note</u>**: The "NIC" field is closely associated with the "SIL" field (defined in subparagraph 2.2.4.5.4.6). The value of the "SIL" field is the probability of the true position lying outside the containment radius, R_C, without alerting, including the effects of airborne equipment condition, which airborne equipment is in use, and which external signals are used.*

2.2.4.5.2.5 "A/G STATE" Field Encoding

The Air/Ground State ("A/G STATE") field is a 3-bit (bits 1 through 3 of byte 13) field that indicates the format used for representing horizontal velocity. The value of this field determines the encoding of the "HORIZONTAL VELOCITY" field. The "A/G STATE" field is composed of three (3) 1-bit fields used as follows:

1. The <u>Vertical Status</u> bit (bit 1 of byte 13) is used to reflect the AIRBORNE or ON-GROUND condition as determined in subparagraph 2.2.4.5.2.5.1.

2. The <u>Subsonic/Supersonic</u> bit (bit 2 of byte 13) is used to indicate the scale factor for the velocity information. The Subsonic/Supersonic bit (bit 2 of byte 13) **shall** be set to ONE (1) if either the East – West velocity OR the North – South velocity, OR the Airspeed exceeds 1022 knots. The Subsonic/Supersonic bit (bit 2 of byte 13) **shall** be reset to ZERO (0) if the East - West and the North - South velocities, OR the Airspeed drop below 1000 knots.

3. The Geometric Reference/Air Reference bit (bit 3 of byte 13) is used to indicate whether the velocity information is based on geometric reference sensors (navigation system), or, if geometric-based velocity is not available, then on air reference sensors (Heading and Airspeed).

If this indication is present in the UAT Transmitting System, and if the AIRBORNE/ON-GROUND Indication input becomes "unavailable" after the "Data Lifetime" timeout listed for this input in Table 2.2.7.1, then the "A/G STATE" field **shall** default to a value of ALL ZEROs.

The encoding of "A/G STATE" field **shall** be as indicated in Table 2.2.4.5.2.5.

Table 2.2.4.5.2.5: "A/G STATE" Encoding

Ownship Conditions	"A/G STATE" Field Encoding				**Resulting "HORIZONTAL VELOCITY" Subfield Formats**	
	MSB		LSB			
	Vertical Status (bit 1 of byte 13)	Subsonic/Supersonic (bit 2 of byte 13)	Geometric/Air Ref. (bit 3 of byte 13)	(decimal)	"North Velocity **or** Airspeed **or** Ground Speed" Subfield Meaning	"East Velocity **or** Track Angle/Heading" Subfield Meaning
AIRBORNE condition. Subsonic condition. Geometric referenced velocity available.	0	0	0	0	North Velocity (LSB = 1 kt)	East Velocity (LSB = 1 kt)
AIRBORNE condition. Subsonic condition. Geometric reference velocity not available.	0	0	1	1	Airspeed (LSB = 1 kt)	Heading
AIRBORNE condition. Supersonic condition. Geometric referenced velocity available.	0	1	0	2	North Velocity (LSB = 4 kts)	East Velocity (LSB = 4 kts)
AIRBORNE condition. Supersonic condition. Geometric referenced velocity not available.	0	1	1	3	Airspeed (LSB = 4 kts)	Heading
<Reserved>	1	0	0	4		
ON GROUND condition.	1	0	1	5	Ground Speed (LSB = 1 kts)	Track/Heading
<Reserved>	1	1	0	6		
<Reserved>	1	1	1	7		

2.2.4.5.2.5.1 Determination of Vertical Status

The ADS-B Transmitting System **shall** determine its Vertical Status (i.e., AIRBORNE or ON-GROUND condition) using the procedure below.

a. If there is a means to automatically determine the Vertical Status of the ADS-B emitter target category, then such information **shall** be used to determine the Vertical Status.

Note: *An "automatic" means of determining vertical status could come from a weight-on-wheels or strut switch, etc. Landing gear deployment is not considered a suitable automatic means.*

b. If there is no means to automatically determine the Vertical Status of the ADS-B transmitter, then the ADS-B transmitter **shall** assume the AIRBORNE condition except under the conditions given for each of the ADS-B Emitter Category types given in Table 2.2.4.5.2.5.1. If the conditions given in Table 2.2.4.5.2.5.1 are met for the given ADS-B Emitter Category, then the ADS-B transmitter **shall** be in the ON-GROUND condition.

<u>Table 2.2.4.5.2.5.1:</u> Determination of ON-GROUND Condition when there is no means to automatically determine Vertical Status

Emitter Category	**Ground Speed**		**Airspeed** (if available)		**Radio Altitude** (if available)
No aircraft type information	Always declare AIRBORNE condition				
Light (ICAO) < 15,500 lbs	Always declare AIRBORNE condition				
Small – 15,500 to 75,000 lbs	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Large – 75,000 to 300,000 lbs	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
High Vortex Large (e.g., B757)	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Heavy (ICAO) - > 300,000 lbs	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Highly Maneuverable > 5G acceleration and high speed	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Rotocraft	Always declare AIRBORNE condition (See Note 1)				
Glider/sailplane	Always declare AIRBORNE condition				
Lighter than air	Always declare AIRBORNE condition (See Note 2)				
Parachutist/sky diver	Always declare AIRBORNE condition				
Ultra light/hang glider/paraglider	Always declare AIRBORNE condition				
Unmanned aerial vehicle	Always declare AIRBORNE condition				
Space/trans-atmospheric vehicle	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Surface vehicle—emergency vehicle	Always declare ON-GROUND condition				
Surface vehicle—service vehicle	Always declare ON-GROUND condition				
Point Obstacle (includes tethered balloons)	See note 3				
Cluster Obstacle					
Line Obstacle					

<u>Notes:</u>

1. *Because of the unique operating capabilities of rotorcraft, i.e., hover, etc., an operational rotorcraft will always report the AIRBORNE condition unless the ONGROUND condition is specifically declared in compliance with subparagraph "a." above.*

2. *Because of the unique operating capabilities of "Lighter-than-Air" vehicles, i.e., balloons, and operational "Lighter-than-Air" vehicle will always report the*

AIRBORNE condition unless the ON GROUND condition is specifically declared in compliance with subparagraph "a." above.

3. *The Vertical Status reported will be appropriate to the situation. In any case the altitude is always present in the transmitted message.*

If "Radio Altitude" is present in the UAT Transmitting System, and if "Radio Altitude" becomes "unavailable" after the "Data Lifetime" timeout listed in Table 2.2.7.1 for this indication, then the "A/G STATE" field **shall** change according to the condition in Table 2.2.4.5.2.5.1.

2.2.4.5.2.5.2 Validation of Vertical Status

When an automatic means of determining Vertical Status indicates ON-GROUND, the Vertical Status **shall** be changed to AIRBORNE under the conditions listed in Table 2.2.4.5.2.5.2.

If "Radio Altitude" is present in the UAT Transmitting System, and if "Radio Altitude" becomes "unavailable" after the "Data Lifetime" timeout listed in Table 2.2.7.1 for this indication, then the "A/G STATE" field **shall** change according to the condition in Table 2.2.4.5.2.5.2.

Note: *The Vertical Status can be used by ADS-B Transmitting Systems to select only the TOP antenna when in the ON-GROUND condition. A false indication of the automatic means could therefore impact signal availability. To minimize this possibility, this validation procedure has been established.*

Table 2.2.4.5.2.5.2: Criteria for Overriding an ON GROUND Condition Determined by Automatic Means

Emitter Category	Ground Speed		Airspeed (if available)		Radio Altitude (if available)
No aircraft type information	No Change to condition				
Light (ICAO) < 15 500 lbs	No Change to condition				
Small - 15 500 to 75 000 lbs	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Large - 75 000 to 300 000 lbs	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
High Vortex Large (e.g., B757)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Heavy (ICAO) - > 300 000 lbs	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Highly Maneuverable > 5G acceleration and high speed	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Rotocraft	No Change to condition				

2.2.4.5.2.6 "HORIZONTAL VELOCITY" Subfields

The "HORIZONTAL VELOCITY" Field is composed of two components:

a. The "North Velocity or Airspeed or Ground Speed" component is represented by an 11-bit subfield from bit 4 of byte 13 through bit 6 of byte 14.

b. The “East Velocity or Track/Heading” component is an 11-bit subfield from bit 7 of byte 14 through bit 1 of byte 16.

Each component can assume multiple formats depending on the “A/G STATE” field. Subparagraphs 2.2.4.5.2.6.1 through 2.2.4.5.2.6.4 describe the encoding for each form of each component.

2.2.4.5.2.6.1 Encoding as “North Velocity” Form

When the “A/G STATE” field is set to “0,” or “2,” the “North Velocity or Airspeed or Ground Speed” component **shall** assume the “North Velocity” format indicated in Table 2.2.4.5.2.6.1.

<u>Table 2.2.4.5.2.6.1:</u> “North Velocity” Format

Byte 13					Byte 14					
Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6
N/S Sign	(MSB)			**--North Velocity Magnitude--**						(LSB)

a. The “N/S Sign” subfield (bit 4 of byte 13) **shall** be used to indicate the direction of the North/South velocity vector as shown in Table 2.2.4.5.2.6.1.a.

<u>Table 2.2.4.5.2.6.1.a:</u> “North/South Sign” Encoding

Coding	Meaning
0	NORTH
1	SOUTH

b. The “North Velocity Magnitude” subfield is a 10-bit (bit 5 of byte 13 through bit 6 of byte 14) subfield that **shall** be used to report the magnitude of the North/South velocity of the ADS-B transmitter. The Range, Resolution and No Data encoding of the “North Velocity Magnitude” subfield **shall** be as shown in Table 2.2.4.5.2.6.1.b.

<u>Table 2.2.4.5.2.6.1.b:</u> “North Velocity Magnitude” Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning (Subsonic Scale)** (A/G State = 0)	**Meaning (Supersonic Scale)** (A/G State = 2)
00 0000 0000	0	N/S Velocity not available	N/S Velocity not available
00 0000 0001	1	N/S Velocity is ZERO	N/S Velocity is ZERO
00 0000 0010	2	N/S Velocity = 1 knots	N/S Velocity = 4 knots
00 0000 0011	3	N/S Velocity = 2 knots	N/S Velocity = 8 knots
…	…	…	…
11 1111 1110	1022	N/S Velocity = 1021 knots	N/S Velocity = 4,084 knots
11 1111 1111	1023	N/S Velocity > 1021.5 knots	N/S Velocity > 4,086 knots

<u>Notes:</u>

1. *The encoding represents Positive Magnitude data only. Direction is given completely by the N/S Sign Bit.*

2. *Raw data used to establish the "North Velocity Magnitude" subfield will normally have more resolution (i.e., more bits) than that required by the "North Velocity Magnitude" subfield. When converting such data to the "North Velocity Magnitude 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 Velocity Magnitude" subfield.*

2.2.4.5.2.6.2 Encoding as "Airspeed or Ground Speed" Form

When the "A/G STATE" field is set to "1," "3," or "5" the "North Velocity or Airspeed or Ground Speed" component **shall** assume the "Airspeed or Ground Speed" format indicated in Table 2.2.4.5.2.6.2. An "A/G STATE" of "1" or "3" **shall** cause Airspeed to be encoded, and an "A/G STATE" of "5" **shall** cause Ground Speed to be encoded.

Table 2.2.4.5.2.6.2: "Airspeed or Ground Speed" Format

Byte 13					Byte 14					
Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6
Format	(MSB)					**--Speed--**				(LSB)

a. The "Format" 1-bit subfield (bit 4 of byte 13) **shall** be used to indicate the format for Airspeed or Ground Speed information as shown in Table 2.2.4.5.2.6.2.a.

Table 2.2.4.5.2.6.2.a: "Format" Encoding

Coding Bit 4	**Meaning**
0	Airspeed (IAS)
1	Airspeed (TAS)

b. The "Speed" subfield is a 10-bit (bit 5 of byte 13 through bit 6 of byte 14) subfield that **shall** be used to report the Airspeed or Ground Speed of the ADS-B transmitter (in knots). The Range, Resolution and No Data encoding of the "Speed" subfield **shall** be as shown in Table 2.2.4.5.2.6.2.b.

Table 2.2.4.5.2.6.2.b: "Speed" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning (Subsonic)** **(A/G State = 1 or 5)**	**Meaning (Supersonic)** **(A/G State = 3)**
00 0000 0000	0	Airspeed or Ground Speed information not available	Airspeed information not available
00 0000 0001	1	Airspeed or Ground Speed is ZERO	Airspeed is ZERO
00 0000 0010	2	Airspeed or Ground Speed = 1 knots	Airspeed = 4 knots
00 0000 0011	3	Airspeed or Ground Speed = 2 knots	Airspeed = 8 knots
…	**…**	**…**	**…**
11 1111 1110	1022	Airspeed or Ground Speed = 1021 knots	Airspeed = 4,084 knots
11 1111 1111	1023	Airspeed or Ground Speed > 1021.5 knots	Airspeed > 4,086 knots

Note: *Raw data used to establish the "Speed" subfield will normally have more resolution (i.e., more bits) than that required by the "Speed" subfield. When converting such data to the "Speed" 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 "Speed" subfield.*

2.2.4.5.2.6.3 Encoding as "East Velocity" Form

When the "A/G STATE" field is set to "0" or "2," the "East Velocity or Track Angle/Heading" component **shall** assume the "East Velocity" format indicated in Table 2.2.4.5.2.6.3.

Table 2.2.4.5.2.6.3: "East Velocity" Format

Byte 14		Byte 15								Byte 16
Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1
E/W Sign	(MSB)				**--East Velocity Magnitude--**					(LSB)

a. The "E/W Sign" subfield (bit 7 of byte 14) **shall** be used to indicate the direction of the East/West velocity vector as shown in Table 2.2.4.5.2.6.3.a.

Table 2.2.4.5.2.6.3.a: "East/West Sign" Encoding

Coding	Meaning
0	EAST
1	WEST

b. The "East Velocity Magnitude" subfield is a 10-bit (bit 8 of byte 14 through bit 1 of byte 16) subfield that **shall** be used to report the East/West velocity of the ADS-B transmitter (in knots). The Range, Resolution and No Data encoding of the "East Velocity Magnitude" subfield **shall** be as shown in Table 2.2.4.5.2.6.3.b.

Table 2.2.4.5.2.6.3.b: "East Velocity Magnitude" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning (Subsonic Scale) (A/G State = 0)**	**Meaning (Supersonic Scale) (A/G State = 2)**
00 0000 0000	0	E/W Velocity not available	E/W Velocity not available
00 0000 0001	1	E/W Velocity is ZERO	E/W Velocity is ZERO
00 0000 0010	2	E/W Velocity = 1 knots	E/W Velocity = 4 knots
00 0000 0011	3	E/W Velocity = 2 knots	E/W Velocity = 8 knots
…	…	…	…
11 1111 1110	1022	E/W Velocity = 1021 knots	E/W Velocity = 4,084 knots
11 1111 1111	1023	E/W Velocity > 1021.5 knots	E/W Velocity > 4,086 knots

Notes:

1. *The encoding represents Positive Magnitude data only. Direction is given completely by the E/W Sign Bit.*

2. *Raw data used to establish the "East Velocity Magnitude" subfield will normally have more resolution (i.e., more bits) than that required by the "East Velocity Magnitude" subfield. When converting such data to the "East Velocity Magnitude" 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 "East Velocity Magnitude" subfield.*

2.2.4.5.2.6.4 Encoding as "Track Angle/Heading" Form

When the "A/G STATE" field is set to "1," "3," or "5" the "East Velocity or Track Angle/Heading" component **shall** assume the "Track Angle/Heading" format indicated in Table 2.2.4.5.2.6.4. An "A/G STATE" of "1" or "3" **shall** cause Heading to be encoded. An "A/G STATE" of "5" **shall** cause Heading to be encoded if available; if not available Track Angle shall be encoded.

Table 2.2.4.5.2.6.4: "Track Angle/Heading" Format

Byte 14		Byte 15								Byte 16
Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1
TA/H Type		(MSB)				**--Track Angle/Heading--**				(LSB)

a. The Track Angle/Heading Type ("TA/H Type") is a 2-bit subfield (bit 7 and 8 of byte 14) that **shall** be used to distinguish Track Angle from Heading as shown in Table 2.2.4.5.2.6.4.a.

Table 2.2.4.5.2.6.4.a: "Track Angle/Heading" Encoding

Coding	Meaning
00	Data Not Available
01	True Track Angle
10	Magnetic Heading
11	True Heading

b. The "Track Angle/Heading" subfield is a 9-bit (bit 1 of byte 15 through bit 1 of byte 16) subfield that **shall** be used to report the Track Angle or Heading of the ADS-B transmitter as shown in Table 2.2.4.5.2.6.4.b.

Table 2.2.4.5.2.6.4.b: "Track Angle/Heading" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	Coding (decimal)	Meaning
0 0000 0000	0	Track Angle/Heading is ZERO
0 0000 0001	1	Track Angle/Heading = 0.703125 degrees
0 0000 0010	2	Track Angle/Heading = 1.406250 degrees
0 0000 0011	3	Track Angle/Heading = 2.109375 degrees
…	…	…
1 1111 1110	510	Track Angle/Heading = 358.593750 degrees
1 1111 1111	511	Track Angle/Heading = 359.296875 degrees

Note: *Raw data used to establish the "Track Angle/Heading" subfield will normally have more resolution (i.e., more bits) than that required by the "Track Angle/Heading" subfield. When converting such data to the "Track Angle/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 "Track Angle/Heading" subfield.*

2.2.4.5.2.7 “VERTICAL VELOCITY OR A/V SIZE” Field

2.2.4.5.2.7.1 Encoding as “Vertical Velocity” Form

When the ADS-B transmitter is in the AIRBORNE condition, the format for the “VERTICAL VELOCITY OR A/V SIZE” field **shall** assume the “Vertical Velocity” form as shown in Table 2.2.4.5.2.7.1.

Table 2.2.4.5.2.7.1: “Vertical Velocity” Format

Byte 16							Byte 17			
Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4
VV Src	**VV Sign**	(MSB) **--Vertical Rate--** (LSB)								

2.2.4.5.2.7.1.1 “VV Src” Subfield Encoding

The Vertical Velocity Source (“VV Src”) subfield is a 1-bit (bit 2 of byte 16) field that **shall** be used to indicate the source of Vertical Rate information as defined in Table 2.2.4.5.2.7.1.1.

Table 2.2.4.5.2.7.1.1: “Vertical Velocity Source” Encoding

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

Vertical rate information **shall** come from a Geometric source when the *Precision* condition is met, specifically when:

a. the “NAC_P” value is “10” or “11”, or, if “NAC_P” is not available, then

b. the “NIC” value is “9”, “10” or “11”

Otherwise, the *Non-Precision* condition is in effect and Vertical Rate information **shall** come from a barometric source.

2.2.4.5.2.7.1.2 “VV Sign” Subfield Encoding

The Sign Bit for Vertical Rate (“VV Sign”) subfield is a 1 bit (bit 3 of byte 16) field used to indicate the direction of the “Vertical Rate” subfield. Encoding of this subfield **shall** be as indicated in Table 2.2.4.5.2.7.1.2.

Table 2.2.4.5.2.7.1.2: “Sign Bit for Vertical Rate” Encoding

Coding	Meaning
0	UP
1	DOWN

2.2.4.5.2.7.1.3 “Vertical Rate” Subfield Encoding

The “Vertical Rate” subfield is a 9-bit (bit 4 of byte 16 through bit 4 of byte 17) field is used to report the Vertical Rate (in feet/minute) of the ADS-B transmission device.

Range, Resolution, and No Data encoding of the "Vertical Rate" subfield **shall** be as shown in Table 2.2.4.5.2.7.1.3.

Table 2.2.4.5.2.7.1.3: "Vertical Rate" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning**
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 = 32,576 feet / minute
1 1111 1111	511	Vertical Rate > 32,608 feet / minute

Notes:

1. *The encoding shown represents Positive Magnitude data only. Direction is given completely by the Vertical Rate Sign Bit.*

2. *Raw data used to establish the "Vertical Rate" subfield will normally have more resolution (i.e., more bits) than that required by the "Vertical Rate" subfield. When converting such data to the "Vertical Rate" 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 "Vertical Rate" subfield.*

3. *For codes "0" and "1," the sign is encoded as ZERO.*

2.2.4.5.2.7.2 Encoding as "A/V Length and Width Code" Form

When the ADS-B transmitter is in the ON-GROUND condition, the "VERTICAL VELOCITY OR A/V SIZE" field **shall** assume the "A/V Length and Width Code" form as shown in Table 2.2.4.5.2.7.2A. The encoding of the "A/V Length and Width Code" **shall** be as shown in Table 2.2.4.5.2.7.2B.

Table 2.2.4.5.2.7.2A: "A/V Length and Width" Format

Byte 16							Byte 17			
Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4
A/V Length and Width				**Reserved**						

Table 2.2.4.5.2.7.2B: "Aircraft Length and Width" Encoding

A/V - L/W Code (decimal)	**Length Code**			**Width Code**	**Length Category**	**Width Category**
	Bit 2	**Bit 3**	**Bit 4**	**Bit 5**		
0	0	0	0	0	L < 30 m	W < 16.5 m
1				1		16.5 m ≤ W < 33 m
2	0	0	1	0	L < 38 m	W < 30.5 m
3				1		30.5 m ≤ W < 38 m
4	0	1	0	0	L < 46 m	W < 38 m
5				1		38 m ≤ W < 48 m

6	0	1	1	0	L < 54 m	W < 42 m
7				1		42 m ≤ W < 52 m
8	1	0	0	0	L < 62 m	W < 51.5 m
9				1		51.5 m ≤ W < 65 m
10	1	0	1	0	L < 70 m	W < 66.5 m
11				1		66.5 m ≤ W < 74 m
12	1	1	0	0	L < 78 m	W < 69.5 m
13				1		69.5 m ≤ W < 80 m
14	1	1	1	0	L ≥ 78 m	W < 84 m
15				1		W ≥ 84 m

2.2.4.5.2.8 “UTC” Field Encoding

The “UTC” field is a 1-bit field (byte 17, bit 5) that indicates whether the ADS-B transmitting system is in the “UTC Coupled” condition or the “Non-UTC Coupled” condition (subparagraph 2.2.5.). The encoding of this field **shall** be as indicated in Table 2.2.4.5.2.8.

If the UTC 1-PPS Timing Input becomes “unavailable” after the “Data Lifetime” value listed for this input in Table 2.2.7.1, then the “UTC” field **shall** default to a value of ZERO.

Table 2.2.4.5.2.8: “UTC” Encoding

Coding	Meaning
0	Non UTC Coupled Condition
1	UTC Coupled Condition

2.2.4.5.2.9 Reserved Bits

Bits 6 through 8 of byte 17 are reserved for future use and **shall** be set to ZERO when the “ADDRESS QUALIFIER” field is set to “0,” “1,” “4,” or “5.”

2.2.4.5.2.10 Reserved Byte 18 of Payload Type Zero

Byte 18 of the ADS-B Message Payload definition in Table 2.2.4.3, when the Payload Type is ZERO (0) is reserved for future use, and **shall** be set to ALL ZEROs.

2.2.4.5.3 STATE VECTOR Element (For TIS-B)

Format for the STATE VECTOR element used for a TIS-B is defined in Table 2.2.4.5.3. This encoding applies to ADS-B messages with PAYLOAD TYPE CODES of “0” through “10” only when a TIS-B target is being reported (ADDRESS QUALIFIER value is “2” or “3”). Each of the fields shown is defined in subparagraphs 2.2.4.5.3.1 and 2.2.4.5.3.2.

Table 2.2.4.5.3: Format of STATE VECTOR Element (For TIS-B)

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
. . .								
5	Latitude (WGS-84)							
6	Latitude (WGS-84)							
7	Latitude (WGS-84)							Longitude (WGS-84)
8	Longitude (WGS-84)							
9	Longitude (WGS-84)							
10	Longitude (WGS-84)							Alt Type
11	Altitude							
12	Altitude				NIC			
13	A/G State			Horizontal Velocity				
14	Horizontal Velocity							
15	Horizontal Velocity							
16	Horizontal Velocity	Vertical Velocity or Aircraft Length/Width Code						
17	Vertical Velocity or Aircraft Length/Width Code				**TIS-B Site ID**			
. . .								

2.2.4.5.3.1 "TIS-B SITE ID" Field Encoding

The "TIS-B SITE ID" field is a 4-bit (bits 5 through 8 of byte 17) field with the MSB as bit 5 and the LSB as bit 8. See Table 2.2.3.2.2.1.8 for the encoding of this field.

Note: *The "UTC" field is not available for TIS-B transmissions. Since TIS-B transmissions come from ground stations, their "UTC Coupled" status is available in the Ground Uplink message (subparagraph 2.2.3.2.2.1.4).*

2.2.4.5.3.2 Encoding for All Other Fields

The encoding of all other fields is consistent with that of subparagraphs 2.2.4.5.2.1 through 2.2.4.5.2.7.2.

2.2.4.5.4 MODE STATUS Element

Format for the MODE STATUS element is defined in Table 2.2.4.5.4. This encoding **shall** apply to ADS-B messages with PAYLOAD TYPE CODES of "1" and "3." Each of the fields shown is defined in the following subparagraphs.

Table 2.2.4.5.4: Format of MODE STATUS Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
. . .								
18	(MSB) **Emitter Category and Flight ID (Call Sign) Characters#1 and #2** (Base-40 encoding)							
19								(LSB)
20	(MSB) **Flight ID (Call Sign) Characters #3, #4, and #5** (Base-40 Encoding)							
21								(LSB)
22	(MSB) **Flight ID (Call Sign) Characters #6, #7, and #8** (Base 40 Encoding)							
23								(LSB)
24	**Emergency/Priority Status**			**UAT MOPS Version**			**SIL**	
25	(MSB) **Transmit MSO**					(LSB)	**Reserved**	
26	**NACp**				**NACv**			**NIC**$_{\text{baro}}$
27	**Capability Codes**		**Operational Modes**			**True/Mag**	**Reserved**	
28	**Reserved**							
29								
. . .								

2.2.4.5.4.1 "EMITTER CATEGORY" Field

The "EMITTER CATEGORY" field is encoded as a radix 40 value in the range of 0-39. The "EMITTER CATEGORY" field **shall** be encoded as shown in Table 2.2.4.5.4.1.

Table 2.2.4.5.4.1: "EMITTER CATEGORY" Encoding

Base-40 Digit (decimal)	Meaning	Base-40 Digit (decimal)	Meaning
0	No aircraft type information	20	Cluster Obstacle
1	Light (ICAO) < 15 500 lbs	21	Line Obstacle
2	Small - 15 500 to 75 000 lbs	22	(reserved)
3	Large - 75 000 to 300 000 lbs	23	(reserved)
4	High Vortex Large (e.g.,	24	(reserved)
5	Heavy (ICAO) - > 300 000 lbs	25	(reserved)
6	Highly Maneuverable > 5G acceleration and high speed	26	(reserved)
7	Rotocraft	27	(reserved)
8	(Unassigned)	28	(reserved)
9	Glider/sailplane	29	(reserved)
10	Lighter than air	30	(reserved)
11	Parachutist/sky diver	31	(reserved)
12	Ultra light/hang	32	(reserved)
13	(Unassigned)	33	(reserved)
14	Unmanned aerial vehicle	34	(reserved)
15	Space/transatmospheric	35	(reserved)
16	(Unassigned)	36	(reserved)
17	Surface vehicle — emergency	37	(reserved)
18	Surface vehicle — service	38	(reserved)
19	Point Obstacle (includes tethered balloons)	39	(reserved)

2.2.4.5.4.2 "FLIGHT ID" Field

The FLIGHT ID field consists of eight characters, which must be decimal digits, uppercase letters, or the space character. The 37 possible different characters are represented as Base-40 digits in the range from 0 to 36. Each character of the "FLIGHT ID" field **shall** be encoded as shown in Table 2.2.4.5.4.2. The left-most character of the Flight ID corresponds to Character #1; the right-most corresponds to Character #8.

If the Flight ID is not available, then all eight characters of the Flight ID Field **shall** be set to the Base-40 digit code 37.

The 8 characters of the "FLIGHT ID" field **shall** be encoded with an identifier appropriate for the Emitter Category, operating rules, and procedures under which the A/V is operating. For aircraft, the "FLIGHT ID" could be an abbreviation of the authorized radiotelephone call sign for that aircraft as assigned by ATS, the aircraft registration marking, or other authorized identifier for special operations.

Note: *A Flight ID of less than 8 characters should be padded with spaces in the right-most (trailing) positions. The first character should not be a space.*

Table 2.2.4.5.4.2: "FLIGHT ID" Character Encoding

Base-40 Digit (decimal)	Character	Base-40 Digit (decimal)	Character
0	0	20	K
1	1	21	L
2	2	22	M
3	3	23	N
4	4	24	O
5	5	25	P
6	6	26	Q
7	7	27	R
8	8	28	S
9	9	29	T
10	A	30	U
11	B	31	V
12	C	32	W
13	D	33	X
14	E	34	Y
15	F	35	Z
16	G	36	SPACE
17	H	37	Not Available
18	I	38	(reserved)
19	J	39	(reserved)

2.2.4.5.4.3 Compressed Format Encoding for "EMITTER CATEGORY" and "FLIGHT ID"

Six bytes (byte 18 through byte 23) are used to encode the "EMITTER CATEGORY" and "FLIGHT ID" fields. Each of three byte pairs are encoded as the binary equivalent of the Base-40 numeral generated as:

$$B_2 x 40^2 + B_1 x 40 + B_0$$

Where the values B_2, B_1 and B_0 are given in subparagraphs 2.2.4.5.4.3.1 through 2.2.4.5.4.3.3.

2.2.4.5.4.3.1 Bytes 18 and 19

Bytes 18 and 19 **shall** be encoded such that:

B_2 - Represents the "EMITTER CATEGORY" field (subparagraph 2.2.4.5.4.1)

B_1 - Represents Character #1 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

B_0 - Represents Character #2 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

2.2.4.5.4.3.2 Bytes 20 and 21

Bytes 20 and 21 **shall** be encoded such that:

B_2 - Represents Character #3 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

B_1 - Represents Character #4 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

B_0 - Represents Character #5 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

2.2.4.5.4.3.3 Bytes 22 and 23

Bytes 22 and 23 **shall** be encoded such that:

B_2 - Represents Character #6 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

B_1 - Represents Character #7 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

B_0 - Represents Character #8 of the "FLIGHT ID" field (subparagraph 2.2.4.5.4.2)

2.2.4.5.4.4 "EMERGENCY/PRIORITY STATUS" Field Encoding

The "EMERGENCY/PRIORITY STATUS" field is a 3-bit (bits 1 through 3 of byte 24) field. The encoding of this field **shall** be as indicated in Table 2.2.4.5.4.4.

If the Emergency/Priority Status Selection Input becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "EMERGENCY/PRIORITY STATUS" field **shall** default to a value of ALL ZEROs.

Table 2.2.4.5.4.4: "EMERGENCY/PRIORITY STATUS" Encoding

Status Code bits $_{MSB}$(Binary)$_{LSB}$	**Status Code bits** (Decimal)	**Meaning**
000	0	No emergency/Not reported
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)

2.2.4.5.4.5 "UAT MOPS VERSION" Field Encoding

The "UAT MOPS VERSION" field is a 3-bit (bits 4 through 6 of byte 24) field. The encoding of this field **shall** be internally hard coded to ONE (binary 001) by all ADS-B Transmitting Systems for equipment complying with this MOPS.

Table 2.2.4.5.4.5: UAT MOPS Version Number

UAT MOPS VN bits $_{MSB}$(Binary)$_{LSB}$	UAT MOPS Version # (Decimal)	Meaning
000	0	Reserved
001	1	Conformant to the initial UAT MOPS
010	2	Reserved
011	3	Reserved
100	4	Reserved
101	5	Reserved
110	6	Reserved
111	7	Reserved

Note: *The UAT MOPS Version Number of ONE (binary 001) corresponds to an ADS-B MASPS Version Number of ONE.*

2.2.4.5.4.6 "SIL" Field Encoding

The Surveillance Integrity Level ("SIL") field is a 2-bit (bits 7 and 8 of byte 24) field used to define the probability of the integrity containment radius, used in the "NIC" field, being exceeded, without alerting. This includes the effects of airborne equipment condition, which airborne equipment is in use, and which external signals are being used by the navigation source. The encoding of the "SIL" field **shall** be as indicated in Table 2.2.4.5.4.6.

If the "SIL" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "SIL" field **shall** default to a value of ALL ZEROs.

Table 2.2.4.5.4.6: "SIL" Encoding.

SIL (binary)	SIL (decimal)	Probability of Exceeding the R_C Integrity Containment Radius Without Detection	Comment
00	0	Unknown	"No Hazard Level" Navigation Source
01	1	1×10^{-3} per flight hour or per operation	"Minor Hazard Level" Navigation Source
10	2	1×10^{-5} per flight hour or per operation	"Major Hazard Level" Navigation Source
11	3	1×10^{-7} per flight hour or per operation	"Severe Major Hazard Level" Navigation Source

Note: *It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used. Thus, for example, if an ADS-B participant reports a NIC code of 0 because four or fewer satellites are available for a GPS fix, there would be no need to change the SIL code until a different navigation source were selected for the positions being reported in the SV report.*

2.2.4.5.4.7 "TRANSMIT MSO" Field Encoding

The "TRANSMIT MSO" field is a 6-bit (bits 1 through 6 of byte 25) field that **shall** be used to encode the 6 LSBs of the Message Start Opportunity (subparagraph 2.2.6.2.1) determined for this message transmission.

2.2.4.5.4.8 Reserved Bits

Bits 7 and 8 of byte 25 are reserved for future use and **shall** be set to ALL ZEROs for equipment conforming to this MOPS.

Note: *This field is reserved for future reporting of Barometric Altitude Quality (BAQ).*

2.2.4.5.4.9 "NAC_P" Field Encoding

The Navigation Accuracy Category for Position ("NAC_P") field is a 4-bit (bits 1 through 4 of byte 26) field used for applications to determine if the reported State Vector has sufficient position accuracy for the intended use. The encoding of the "NAC_P" field **shall** be as indicated in Table 2.2.4.5.4.9.

If the "NAC_P" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "NAC_P" field **shall** default to a value of ALL ZEROs.

Table 2.2.4.5.4.9: "NAC_P" Encoding

NAC_P (binary)	NAC_P (decimal)	95% Horizontal and Vertical Accuracy Bounds (EPU and VEPU)	Comment	Notes
0000	0	EPU ≥ 18.52 km (10 NM)	Unknown accuracy	
0001	1	EPU < 18.52 km (10 NM)	RNP-10 accuracy	1
0010	2	EPU < 7.408 km (4 NM)	RNP-4 accuracy	1
0011	3	EPU < 3.704 km (2 NM)	RNP-2 accuracy	1
0100	4	EPU < 1852 m (1NM)	RNP-1 accuracy	1
0101	5	EPU < 926 m (0.5 NM)	RNP-0.5 accuracy	1
0110	6	EPU < 555.6 m (0.3 NM)	RNP-0.3 accuracy	1
0111	7	EPU < 185.2 m (0.1 NM)	RNP-0.1 accuracy	1
1000	8	EPU < 92.6 m (0.05 NM)	e.g., GPS (with SA)	
1001	9	EPU < 30 m and VEPU < 45 m	e.g., GPS (SA off)	2
1010	10	EPU < 10 m and VEPU < 15 m	e.g., WAAS	2
1011	11	EPU < 3 m and VEPU < 4 m	e.g., LAAS	2
1100	12	(Reserved)		
1101	13	(Reserved)		
1110	14	(Reserved)		
1111	15	(Reserved)		

Notes:

1. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

2. *If geometric altitude is not being reported then the VEPU tests are not assessed.*

3. *The Estimated Position Uncertainty (EPU) used in 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 being outside the*

circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).

4. *Likewise, Vertical Estimated Position Uncertainty (VEPU) is a 95% accuracy limit on the vertical position. VEPU is defined as a vertical position limit, such that the probability of the actual vertical position differing from the reported vertical position by more than that limit is 0.05. When reported by a GPS or GNSS system, VEPU is commonly called VFOM (Vertical Figure of Merit).*

2.2.4.5.4.10 "NAC_V" Field Encoding

The Navigation Accuracy Category for Velocity ("NACv") field is a 3-bit (bits 5 through 7 of byte 26) field used for applications to determine if the reported State Vector has sufficient velocity accuracy for the intended use. The "NAC_V" field reflects the least accurate velocity component being transmitted. The "NAC_V" field **shall** be encoded as indicated in Table 2.2.4.5.4.10.

If the "NAC_V" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "NAC_V" field **shall** default to a value of ALL ZEROs.

<u>Table 2.2.4.5.4.10:</u> "NAC_V" Encoding.

NAC_V (binary)	NAC_V (decimal)	Horizontal Velocity Error (95%)	Vertical Geometric Velocity Error (95%)
000	0	Unknown or ≥ 10 m/s	Unknown or ≥ 50 feet (15.24 m) per second
001	1	< 10 m/s	< 50 feet (15.24 m) per second
010	2	< 3 m/s	< 15 feet (4.57 m) per second
011	3	< 1 m/s	< 5 feet (1.52 m) per second
100	4	< 0.3 m/s	< 1.5 feet (0.46 m) per second
101	5	(Reserved)	(Reserved)
110	6	(Reserved)	(Reserved)
111	7	(Reserved)	(Reserved)

2.2.4.5.4.11 "NIC_{BARO}" Field Encoding

The Barometric Altitude Integrity Code ("NIC_{BARO}") field is a 1-bit (bit 8 of byte 26) field that indicates whether or not the barometric pressure altitude provided in the State Vector element of the payload has been cross checked against another source of pressure altitude. The "NIC_{BARO}" field **shall** be encoded as indicated in Table 2.2.4.5.4.11.

If the "NIC_{BARO}" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "NIC_{BARO}" field **shall** default to a value of ZERO.

<u>Table 2.2.4.5.4.11:</u> "NIC_{BARO}" Encoding

Coding	Meaning
0	Barometric Pressure Altitude has NOT been cross checked
1	Barometric Pressure Altitude has been cross checked

2.2.4.5.4.12 "CAPABILITY CODES" Field Encoding

The "CAPABILITY CODES" field is a 2-bit (bits 1 and 2 of byte 27) field used to indicate the capability of a participant to support engagement in various operations. The "CAPABILITY CODES" field **shall** be encoded as indicated in Table 2.2.4.5.4.12.

Note: *The Target State (TS) Report Capability flag, the TC Report capability level and the ARV Report Capability flag can be inferred from the UAT transmissions of A1, A2 and A3 system participants. Reference RTCA Document DO-242A, Table 3.4.-4.*

Table 2.2.4.5.4.12: "CAPABILITY CODES" Encoding

Byte #	Bit #	Encoding
Byte 27	Bit 1	CDTI Traffic Display Capability. 0 = NO 1 = YES
	Bit 2	TCAS/ACAS Installed and Operational. 0 = NO 1 = YES

2.2.4.5.4.12.1 "CDTI Traffic Display Capability" Subfield

The Capability Code for "Cockpit Display of Traffic Information (CDTI) traffic display capability" **shall** be set to ONE if the transmitting aircraft has the capability of displaying nearby traffic on a CDTI. Otherwise, this code **shall** be ZERO.

If the "CDTI Traffic Display Capability" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "CDTI Traffic Display Capability" field **shall** default to a value of ZERO.

2.2.4.5.4.12.2 "TCAS/ACAS Installed and Operational" Subfield

The Capability Code for "TCAS/ACAS installed and operational" **shall** be set to ONE if the transmitting aircraft is fitted with a TCAS (ACAS) computer and that computer is turned on and operating in a mode that can generate Resolution Advisory (RA) alerts. Otherwise, this Capability Code **shall** be ZERO.

If the "TCAS/ACAS installed and operational" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "TCAS/ACAS installed and operational" field **shall** default to a value of ZERO.

2.2.4.5.4.13 "OPERATIONAL MODES" Field Encoding

The "OPERATIONAL MODES" field is a 3-bit (bits 3 through 5 of byte 27) field used to indicate the capability of a participant to support engagement in various operations. The "OPERATIONAL MODES" field **shall** be encoded as indicated in Table 2.2.4.5.4.13.

Table 2.2.4.5.4.13: "OPERATIONAL MODES" Encoding

Byte #	Bit #	Encoding
Byte 27	Bit 3	TCAS/ACAS Resolution Advisory Active Flag. 0 = NO 1 = YES
	Bit 4	IDENT Switch Active Flag. 0 = NOT Active (> 20 seconds since activated by pilot) 1 = Active (<= 20 seconds since activated by pilot)
	Bit 5	"Receiving ATC Services" Flag 0 = NOT Receiving ATC Services 1 = Receiving ATC Services

2.2.4.5.4.13.1 "TCAS/ACAS Resolution Advisory" Flag

A transmitting ADS-B participant **shall** set the TCAS/ACAS Resolution Advisory Active Flag to ONE in the messages that it transmits to support the MS report so long as a TCAS/ACAS resolution advisory is in effect. At all other times, the transmitting ADS-B participant **shall** set the TCAS/ACAS Resolution Advisory Active Flag to ZERO.

If the "TCAS/ACAS Resolution Advisory" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "TCAS/ACAS Resolution Advisory" field **shall** default to a value of ZERO.

2.2.4.5.4.13.2 "IDENT Switch Active " Flag

The "IDENT Switch Active" Flag is activated by an IDENT switch. Initially, the "IDENT switch active" code is ZERO. Upon activation of the IDENT switch, this flag **shall** be set to ONE in all scheduled ADS-B messages containing the MODE STATUS element for an interval of 20 seconds +/-4 seconds. After the time interval expires, the flag **shall** be set to ZERO.

If the "IDENT Switch Active" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "IDENT Switch Active" field **shall** default to a value of ZERO.

Note: *This allows an ATC ground station 4-5 reception opportunities to receive the IDENT indication.*

2.2.4.5.4.13.3 "Receiving ATC Services" Flag

The "Receiving ATC Services" flag is based on a pilot setting. This flag **shall** be set to ONE to indicate that the transmitting ADS-B participant is receiving ATC services; when not receiving ATC services, a transmitting ADS-B participant should set this flag to ZERO.

If the "Receiving ATC Services" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "Receiving ATC Services" field **shall** default to a value of ZERO.

Note: *This provides for a ground ATC system to identify an aircraft that is receiving ATC services, similar to an SSR transponder providing a squawk code of other than "1200."*

2.2.4.5.4.14 True/Magnetic Heading Flag

The True/Magnetic Heading Flag in the Mode-Status Element is a one-bit field (bit 6 of byte 27) which **shall** be set to ZERO to indicate that heading is reported referenced to true north, or set to ONE to indicate that heading is reported referenced to magnetic north. This True/Magnetic Heading Flag supports the "Heading/Track Indicator" Flag in the TARGET STATE Element defined in subparagraph 2.2.4.5.6.1.2.

If the "True/Magnetic Heading Flag" field becomes "unavailable" after the "Data Lifetime" value listed for this input in Table 2.2.7.1, then the "True/Magnetic Heading Flag" field **shall** default to a value of ZERO.

2.2.4.5.4.15 Reserved Bits

This Reserved Bits field is a 18-bit (bit 7 of byte 27 through bit 8 of byte 29) field used that may be used in the future to indicate the capability of a participant to support engagement in various operations. This Reserved Bits field is reserved for future use and **shall** be set to ALL ZEROs.

2.2.4.5.5 AUXILIARY STATE VECTOR Element

Format for the AUXILIARY STATE VECTOR element is defined in Table 2.2.4.5.5. This encoding **shall** apply to ADS-B messages with "PAYLOAD TYPE CODES" of "1," "2," "5," and "6." Each of the fields shown is defined in the following subparagraphs.

Table 2.2.4.5.5: Format of AUXILIARY STATE VECTOR Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
. . .								
30	(MSB)			**Secondary Altitude**				
31				(LSB)				
32								
33				**Reserved**				
34								
. . .								

2.2.4.5.5.1 "SECONDARY ALTITUDE" Field Encoding

The "SECONDARY ALTITUDE" field is a 12-bit (bit 1 of byte 30 through bit 4 of byte 31) field used to encode either the geometric altitude or barometric pressure altitude depending on the setting of the "ALTITUDE TYPE" field (subparagraph 2.2.4.5.2.2). The altitude encoded in the "SECONDARY ALTITUDE" field is the opposite type to that specified by the "ALTITUDE TYPE field. The encoding **shall** be consistent with that used for "ALTITUDE" described in Table 2.2.4.5.2.3.

2.2.4.5.5.2 Reserved Bits

Bit 5 of byte 31 through bit 8 of byte 34 are reserved for future use, and **shall** be set to ALL ZEROs.

Note: *This field is reserved for future definition to contain either Air-Referenced Velocity or perhaps wind vector and temperature.*

2.2.4.5.6 TARGET STATE Element (Payload Type Codes "3" and "4")

Format for the TARGET STATE element is defined in Table 2.2.4.5.6. This encoding **shall** apply to ADS-B messages with "PAYLOAD TYPE CODES" of "3" and "4."

Table 2.2.4.5.6: Format of TARGET STATE Element (Payload Type Codes "3" and "4")

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
.								
.								
30	**Target Heading or Track Angle**							
31	**Target Heading or Track Angle** (cont.)							(bit 8: Target Altitude)
32	**Target Altitude**							
33	**Target Altitude**							
.								
.								

2.2.4.5.6.1 "TARGET HEADING OR TRACK ANGLE" Field Encoding

The "TARGET HEADING OR TRACK ANGLE" field is composed of subfields as indicated in Table 2.2.4.5.6.1.

Table 2.2.4.5.6.1: "TARGET HEADING OR TRACK ANGLE" Format

Byte 30							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
Hdg/Trk	**Target Source Indicator (H).**		**Mode Indicator (H)**	**Reserved**		(MSB)	
Byte 31							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	
-- Track Heading or Track Angle --						(LSB)	

2.2.4.5.6.1.1 "Heading/Track Indicator" Flag Encoding

The "Heading/Track Indicator" flag (bit 1 of byte 30) **shall** be set to ZERO to indicate that the "Target Heading or Track Angle" subfield conveys target heading, or ONE to indicate that it conveys target track angle. The reference direction (true north or magnetic north) is conveyed in the "True/Magnetic Heading Flag" of the Mode Status Element referenced in subparagraph 2.2.4.5.4.14.

If this indication is present in the UAT Transmitting System, and if the "Heading/Track Indicator" field becomes "unavailable" after the "Data Lifetime" timeout listed for this field in Table 2.2.7.1, then the "Heading/Track Indicator" field **shall** default to a value of ZERO.

2.2.4.5.6.1.2 "Target Source Indicator (Horizontal)" Subfield Encoding

The "Target Source Indicator (Horizontal)" is a 2-bit (bits 2 and 3 of byte 30) field that indicates the source of Target Heading/Track Angle information. The encoding of this field **shall** be as indicated in Table 2.2.4.5.6.1.2.

Table 2.2.4.5.6.1.2: "Target Source Indicator (Horizontal) Encoding

Bit 2, Byte 30	Bit 3, Byte 30	**Encoding (decimal)**	**Meaning**
0	0	0	No Valid Horizontal Target State data is available
0	1	1	Autopilot control panel selected value, such as Mode Control Panel (MCP) or Flight Control Unit (FCU)
1	0	2	Maintaining current heading or track angle (e.g., autopilot mode select)
1	1	3	FMS/RNAV system (indicates track angle specified by leg type)

2.2.4.5.6.1.3 "Mode Indicator (Horizontal)" Flag Encoding

The "Mode Indicator (Horizontal)" 1-bit (bit 4 of byte 30) field that reflects the aircraft's state relative to the target heading or track angle. A ZERO **shall** be used to reflect that the target heading or track angle is being *Acquired* and a ONE **shall** be used to indicate that the target heading or track angle is being *Captured or Maintained*.

If this indication is present in the UAT Transmitting System, and if the "Mode Indicator (Horizontal)" field becomes "unavailable" after the "Data Lifetime" timeout listed for this field in Table 2.2.7.1, then the "Mode Indicator (Horizontal)" field **shall** default to a value of ZERO.

2.2.4.5.6.1.4 Reserved Bits

Bits 5 and 6 of byte 30 are reserved for future use and **shall** always be set to ZERO.

2.2.4.5.6.1.5 "Target Heading or Track Angle" Subfield Encoding

The "Track Angle/Heading" subfield is a 9-bit (bit 7 of byte 30 through bit 7 of byte 31) subfield that **shall** be used to report the Track Angle or Heading of the ADS-B transmitter as shown in Table 2.2.4.5.6.1.5.

If this indication is present in the UAT Transmitting System, and if the "Track Angle/Heading" field becomes "unavailable" after the "Data Lifetime" timeout listed for this field in Table 2.2.7.1, then the "Track Angle/Heading" field **shall** default to a value of ALL ZEROs.

Table 2.2.4.5.6.1.5: "Target Heading or Track Angle" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning**
0 0000 0000	0	Track Angle/Heading is ZERO degrees
0 0000 0001	1	Track Angle/Heading = 0.703125 degrees
0 0000 0010	2	Track Angle/Heading = 1.406250 degrees
…	…	…
1 1111 1110	510	Track Angle/Heading = 358.593750 degrees
1 1111 1111	511	Track Angle/Heading = 359.296875 degrees

Note: *Raw data used to establish the "Target Heading or Track Angle" subfield will normally have more resolution (i.e., more bits) than that required by the "Target Heading or Track Angle" subfield. When converting such data to the "Target Heading or Track Angle" 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 "Target Heading or Track Angle" subfield.*

2.2.4.5.6.2 "TARGET ALTITUDE" Field Encoding

The "TARGET ALTITUDE" field is a 17-bit (bit 8 of byte 31 through bit 8 of byte 33) field composed of subfields as indicated in Table 2.2.4.5.6.2.

Input from Bob Saffell could simplify this.

Table 2.2.4.5.6.2: "TARGET ALTITUDE" Format

Byte 31							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
							Target Alt. Type
Byte 32							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
Target Source Indicator (V)		**Mode Ind. (V)**	**Target Altitude Capability**		**Reserved**	(MSB)	
Byte 33							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
-- Target Altitude --							(LSB)

2.2.4.5.6.2.1 "Target Altitude Type" Flag Encoding

The "Target Altitude Type" flag is a 1-bit (bit 8 of byte 31) field that indicates whether the target altitude is barometric pressure altitude or flight level (used for target altitudes above the transition level between altitude types), or a locally corrected altitude (used for target altitudes below the transition level). The "Target Altitude Type" **shall** be encoded as indicated in Table 2.2.4.5.6.2.1.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude Type" field becomes "unavailable" after the "Data Lifetime" timeout listed for this field in Table 2.2.7.1, then the "Target Altitude Type" field **shall** default to a value of ZERO.

Note: *This flag is set based on the relationship of the target altitude to the "transition level."*

Table 2.2.4.5.6.2.1: Target Altitude Type Values

Value	Meaning
0	Pressure Altitude ("Flight Level") – target altitude is above transition level
1	Baro-Corrected Altitude ("MSL") – target altitude is below transition level

2.2.4.5.6.2.2 "Target Source Indicator (Vertical)" Subfield Encoding

The "Target Source Indicator (Vertical)" is a 2-bit (bits 1 and 2 of byte 32) field that indicates the source of Target Altitude information. The encoding of this field **shall** be as indicated in Table 2.2.4.5.6.2.2.

Table 2.2.4.5.6.2.2: "Target Source Indicator (Vertical)" Encoding

Bit 4, Byte 32	Bit 5, Byte 32	(decimal)	Meaning
0	0	0	No Valid Vertical Target State data is available
0	1	1	Autopilot Control Panel selected value such as a Mode Control Panel (MCP) or Flight Control Unit (FCU)
1	0	2	Holding Altitude
1	1	3	FMS or RNAV system

2.2.4.5.6.2.3 "Mode Indicator (Vertical)" Flag Encoding

The "Mode Indicator (Vertical)" is a 1-bit (bit 3 of byte 32) field that reflects the aircraft's state relative to the target altitude. A ZERO **shall** be used to reflect that the target altitude is being *Acquired* and a ONE **shall** be used to indicate that the target altitude has been *Captured* or is being *Maintained.*

If this indication is present in the UAT Transmitting System, and if the "Mode Indicator (Vertical)" field becomes "unavailable" after the "Data Lifetime" timeout listed for this field in Table 2.2.7.1, then the "Mode Indicator (Vertical)" field **shall** default to a value of ZERO.

2.2.4.5.6.2.4 "Target Altitude Capability" Subfield Encoding

The "Target Altitude Capability" is a 2-bit (bit 4 and 5 of byte 32) field that describes the value occupying the "Target Altitude" subfield. The encoding of this field **shall** be as indicated in Table 2.2.4.5.6.2.4.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude Capability" field becomes "unavailable" after the "Data Lifetime" timeout listed for this field in Table 2.2.7.1, then the "Target Altitude Capability" field **shall** default to a value of ALL ZEROs.

Table 2.2.4.5.6.2.4: "Target Altitude Capability" Encoding

Bit 7, Byte 32	Bit 8, Byte 32	Meaning
0	0	Capability for holding altitude only
0	1	Capability for either holding altitude, or for autopilot control panel selected altitude
1	0	Capability for either holding altitude, for autopilot control panel selected altitude, or for any FMS/RNAV level-off altitude
1	1	Reserved

2.2.4.5.6.2.5 Reserved Bit

Bit 6 of byte 32 is reserved for future use and **shall** always be set to ZERO.

2.2.4.5.6.2.6 "Target Altitude" Subfield Encoding

"Target Altitude" is a 10-bit (bit 7 of byte 32 through bit 8 of byte 33) field that is the aircraft's next intended level flight altitude if in a climb or descent, or its current intended altitude if commanded to hold altitude. The encoding of this field **shall** be as indicated in Table 2.2.4.5.6.2.6.

Table 2.2.4.5.6.2.6: "Target Altitude" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning**
00 0000 0000	0	Target Altitude information unavailable
00 0000 0001	1	Target Altitude = -1000 feet
00 0000 0010	2	Target Altitude = -900 feet
…	…	…
00 0000 1010	10	Target Altitude = -100 feet
00 0000 1011	11	Target Altitude = ZERO feet
00 0000 1100	12	Target Altitude = 100 feet
…	…	…
11 1111 1110	1022	Target Altitude = 101,100 feet
11 1111 1111	1023	Target Altitude > 101,150 feet

Note: *Raw data used to establish the Target Altitude subfield will normally have more resolution (i.e., more bits) than that required by the Target Altitude subfield. When converting such data to the Target Altitude 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 Target Altitude subfield.*

2.2.4.5.7 TARGET STATE Element (Payload Type Code "6")

Format for the TARGET STATE element is defined in Table 2.2.4.5.7. This encoding **shall** apply to ADS-B messages with "PAYLOAD TYPE CODES" of "6." Each of the fields shown are defined in subparagraphs 2.2.4.5.6.1.5 through 2.2.4.5.6.2.6 with the exception of the byte offset indicated in Table 2.2.4.5.7.

<u>Table 2.2.4.5.7:</u> Format of TARGET STATE Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
				. .				
25	**Target Heading or Track Angle**							
26								
27								
28	**Target Altitude**							
				. .				

2.2.4.5.8 TRAJECTORY CHANGE Element

This element contains 96 bit that are reserved for future definition. Equipment conforming to this MOPS **shall** insert ALL ZEROs in this element whenever present in a transmitted message. See Appendix L to see how this reserved field could be used to meet the requirements of reporting TCR+0 and TCR+1 in the future.

2.2.5 Procedures for Processing of Time Data

UAT equipment derives its timing for transmitter and receiver functions from GPS/GNSS (or equivalent) time sources. The PVT data is presumed to be accurate to within +/- 5 milliseconds of the Time Mark signal to which it applies. Time Mark information is utilized by the UAT equipment in the following ways:

a. Any extrapolation of Position data **shall** comply with the requirements of subparagraph 2.2.7.2.1 and 2.2.7.2.2.

b. The UAT transmit message timing **shall** comply with the requirements of subparagraph 2.2.6.2.1 and 2.2.6.2.2.

c. The UAT receiver time processing **shall** comply with the requirements of subparagraph 2.2.8.3.5.

<u>Notes:</u>

1. *A possible implementation of the GPS/GNSS Time Mark pulse is illustrated in Figure 2.2.5.1, adapted from ARINC Characteristic 743A.*

2. *Determination of time source "equivalence" will be made by appropriate Certification Authorities. Useful information concerning recommended accuracy of such a time source may be found in Appendix I.*

2.2.5.1 UTC Coupled Condition

The "UTC Coupled" subfield **shall** be set to ONE, except under the conditions discussed in subparagraph 2.2.5.2.

<u>Note:</u> *Operation of the UAT system in normal mode presumes GNSS, or equivalent, equipage on system participants to, for example, prevent media access conflict* *with the UAT ground up-link transmissions. Short term GNSS outages are mitigated by UAT ground infrastructure providing timing information and/or the ability to maintain UAT system timing for a minimum of 20 minutes in the absence of GNSS (subparagraph 2.2.5.3[d]). In areas without ground up-link transmissions, there is no media access conflict.*

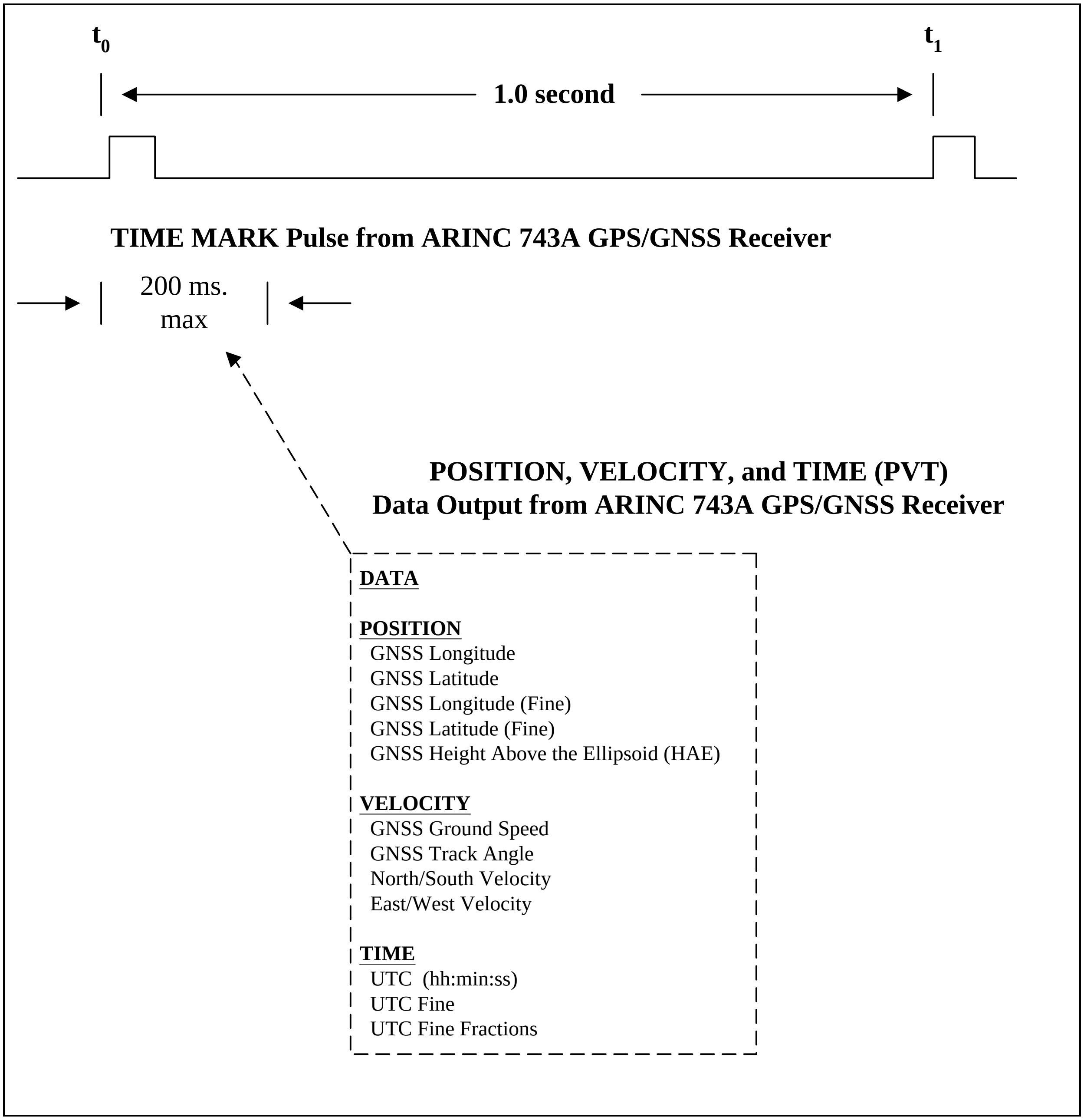

Figure 2.2.5.1: GPS/GNSS Time Mark Pulse

2.2.5.2 Non-UTC Coupled Condition

a. This condition **shall** be entered when the ADS-B equipment has not been provided a GPS/GNSS, or equivalent, time mark. This is not the normal condition; it is a degraded mode of operation.

b. Within 2 seconds of entering the Non-UTC Coupled condition, the UAT equipment **shall** set the "UTC Coupled" subfield to ZERO in any transmitted messages.

c. While in the non-UTC Coupled Condition, Class A0, A1, A2 and A3 equipment with operational receivers **shall** be capable of aligning to within +/- 6 milliseconds of UTC time based upon successful message reception of any Ground Uplink Message with the "UTC Coupled" bit set.

<u>Note</u>: *This assumes that the Ground Uplink message is referenced to UTC 1-second epoch.*

d. While in the non-UTC Coupled Condition when Ground Uplink messages cannot be received, the UAT transmitter **shall** estimate — or "coast" — time through the outage period such that the drift rate of estimated time, relative to actual UTC-coupled time, is no greater than 12 milliseconds in 20 minutes.

e. While in the non-UTC Coupled Condition, ADS-B transmissions **shall** continue.

f. The UAT equipment **shall** change state to the UTC coupled condition within 2 seconds of availability of the UTC coupled source.

<u>Notes:</u>

1. *Item "d" above is consistent with an initial drift rate of 10 PPM in the baud clock over the 12 millisecond air-ground segment guard time. Clock drift can be compensated up to the time coasting begins.*

2. *In the non-UTC Coupled Condition, the estimated 1 second UTC epoch signal does NOT indicate the time of validity of Position, Velocity and Time (PVT) information.*

3. *Any installations of Class A equipment involving separated transmitters and receivers must provide a mechanism to fulfill the requirement stated in subparagraph c) above.*

4. *This reversionary timing exists for the following reasons:(**a**) to support ADS-B message transmission using an alternate source of position and velocity, <u>if available</u>; (**b**) to support ADS-B message transmission in absence of position and velocity data in order that any available fields are conveyed (e.g., barometric altitude) and (**c**) that a signal is provided in the event the ground network can perform an ADS-B-independent localization of the A/V (e.g., multilateration).*

2.2.6 Procedures for ADS-B Message Transmission

2.2.6.1 Scheduling of ADS-B Message Types

2.2.6.1.1 Payload Selection Cycle

A payload selection cycle is defined to ensure the timely transmission of ADS-B messages of up to four different payload types: Payload Selection (PS)-A, PS-B, PS-C, and PS-D.

<u>Note:</u> *Allowing each of the four Payload Selections to propagate over each of four possible transmit/receive antenna combinations requires a transmission period of at least 16 seconds (i.e., 16 = 4 x 4).*

2.2.6.1.2 ADS-B Payload Type Allocation

One of the ADS-B payload types in the range of “0” through “6”specified in Table 2.2.4.3 **shall** be assigned to each of the 4 Payload Selections (PS) as shown in Table 2.2.6.1.2.

<u>Table 2.2.6.1.2:</u> Payload Type Code Allocation

Equipment Class	PS-A	PS-B	PS-C	PS-D
A0, A1L, A1H, B1	1	0	2	0
A1H (see Note 2)	3	6	0	6
A2	1	4	4	4
A3	1	4	5	4
B2, B3	1	0	0	0

<u>Notes:</u>

1. *This schedule is to be followed regardless of the unavailability of any payload fields.*

2. *Optional Payload Type Code assignment if the installation can support transmission of Trajectory State information.*

2.2.6.1.3 Message Transmission Cycle (Transmitter Diversity)

A message transmission cycle of 16 seconds is defined to ensure a proper mix of message payloads for installations that support ADS-B message transmission from dual (diversity) antennas (see subparagraph 2.1). Transmissions **shall** occur through Top (T) and Bottom (B) antennas each Message Transmission Cycle as shown in Figure 2.2.6.1.3.

Antenna	T	T	B	B	T	T	B	B	T	T	B	B	T	T	B	B
PS #	A	B	C	D	D	A	B	C	C	D	A	B	B	C	D	A
Seconds	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Message Transmission Cycle

Time

<u>Figure 2.2.6.1.3</u>: Transmitter Antenna Use for Diversity Installations

<u>Notes</u>:

1. *There is no requirement that transmission cycle boundaries be aligned among A/Vs; it is used only to ensure proper mix of transmitted message types.*

2. *For receivers with antenna diversity provided by switching according to subparagraph 2.2.8.1, this transmission pattern ensures that each payload type is communicated via each possible transmit/receive antenna combination (T/T, T/B, B/T, B/B) once during each 16 second cycle. It also minimizes the maximum spacing between any two transmissions of the same type.*

3. *When an aircraft is known to be operating on the airport surface, aircraft may wish to always select the top antenna (if so equipped) for all transmissions. If a single receiver is switched between two antennas, aircraft may wish to always select the top antenna for reception. If the aircraft has no physical means of determining the on-ground condition, the equipment may use a low threshold of geometric velocity to enable or disable the antenna switch selection method, if it can be shown that such a method is appropriate for the intended application and aircraft operating characteristics.*

2.2.6.2 ADS-B Message Transmit Timing

2.2.6.2.1 The Message Start Opportunity (MSO)

ADS-B Messages **shall** be transmitted at discrete Message Start Opportunities (MSO) chosen by a pseudo-random process. The specific pseudo-random number (*R*) chosen by an aircraft depends on the aircraft's current position and on the previously chosen random number. Let:

N(0) = 12 L.S.B.'s of the most recent valid "LATITUDE"
N(1) = 12 L.S.B.'s of the most recent valid "LONGITUDE"

where the "LATITUDE" and "LONGITUDE" are as defined in subparagraph 2.2.4.1.2 and 2.2.4.1.3 respectively.

The procedure below **shall** be employed to establish the transmission timing for the current UAT frame *m*.

$$R(m) = \{4001 \cdot R(m-1) + N(m \bmod 2)\} \bmod 3200$$

The MSO **shall** be 752 + R(*m*). R(*0*) **shall** be ZERO.

Notes:

1. *Retention of N(0) and N(1) in non-volatile memory is required to prevent common MSO selections amongst A/Vs when no valid latitude and longitude is currently available.*

2. *The latitude and longitude alternate in providing a changing "seed" for the pseudo-random number generation.*

2.2.6.2.2 Relationship of the MSO to the Modulated Data

The optimum sample point of the first bit of the UAT synchronization sequence at the antenna terminal of the UAT equipment **shall** occur at T_{TX} microseconds after the 1 second UTC epoch according to the following formula:

$$T_{TX} \text{ (microseconds)} = 6000 + (250 * \text{MSO})$$

within the following tolerances:

a. +/- 500 nanoseconds for UAT equipment with an internal UTC coupled time source,

b. +/- 500 nanoseconds for UAT equipment with an external UTC coupled time source.

Notes:

1. *This is required to support ADS-B range validation by a receiving application. This requirement sets the ultimate timing accuracy of the transmitted messages under the UTC Coupled condition. See Appendix I for a discussion of UAT Timing Considerations.*

2. *Referencing this measurement to the optimum sampling point is convenient since this is the point in time identified during the synchronization process.*

3. *There is no requirement to demonstrate this relationship when in the non-UTC Coupled condition.*

2.2.6.3 Report Assembly on Transmission of Ownship ADS-B Message

The transmitter **shall** issue a report reflecting each ADS-B message transmission and explicitly identify the report as “own-ship”.

Reports **shall** contain all elements of the transmitted message payload with range and accuracy of each payload field preserved.

Notes:

1. *This is to aid any application process that uses ADS-B message propagation time to perform a validity check of received ADS-B messages by providing a reference point for measured ranges.*

2. *Allows independent monitoring of the transmitted position.*

2.2.7 UAT Transmitter Message Data Characteristics

2.2.7.1 UAT Transmitter Input Requirements

This subparagraph contains requirements for access to the input elements required to compose the ADS-B messages so their bits can be verified for their mapping into the structure of the transmitted message.

a. The UAT ADS-B transmitting device **shall** accept the input data elements listed in Table 2.2.7.1 via an appropriate data input interface and use such data to establish the corresponding ADS-B message contents.

b. Data elements indicated as “Optional,” that have no input interface, **shall** always indicate the “data unavailable” condition.

If the requirements for ADS-B Reference Position Point are retained in DO-242A, we will need to have a position offset input in Table 2.2.7.1.

If R3.3 in DO-242A retains the ability for B1 equipment to transmit at A2 power levels, then Table 2.2.7.1 needs to reflect this capability.

Table 2.2.7.1: **UAT ADS-B Transmitter Input Requirements**

Element #	Input Data Element	Relevant Paragraph	Data Lifetime (seconds)	Applicable UAT Equipment Class						
				A0, B1	A1L	A1H	A2	A3	B2	B3
1	ICAO 24-bit Address	2.2.4.5.1.3.1	n/a	M	M	M	M	M	M	M
2	Address Selection (ICAO vs Temporary)	2.2.4.5.1.3.1 2.2.4.5.1.3.2	60	Input required only if installation is to have selectable address						
3	Latitude	2.2.4.5.2.1	2	If input not directly accessible, a means to verify encoding must be demonstrated						
4	Longitude	2.2.4.5.2.1	2							
5	Altitude Type Selection (Barometric vs Geometric)	2.2.4.5.2.2	60	O	O	O	O	O	n/a	M
6	Barometric Pressure Altitude	2.2.4.5.2.3	2	M	M	M	M	M	n/a	O
7	Geometric Altitude	2.2.4.5.2.3	2	M	M	M	M	M	n/a	M
8	NIC	2.2.4.5.2.4	2	M	M	M	M	M	M	M
9	Automatic AIRBORNE / ON-GROUND Indication	2.2.4.5.2.5	2	O	O	M	M	M	n/a	n/a
10	North Velocity	2.2.4.5.2.6.1	2	If input not directly accessible, a means to verify encoding must be demonstrated						
11	East Velocity	2.2.4.5.2.6.3	2							
12	Airspeed	2.2.4.5.2.6.2	2	O	O	M	M	M	n/a	n/a
13	Track Angle	2.2.4.5.2.6.4	2	O	M	M	M	M	n/a	n/a
14	Heading	2.2.4.5.2.6.4	2	O	O	M	M	M	n/a	n/a
15	Barometric Vertical Rate	2.2.4.5.2.2 2.2.4.5.2.3 2.2.4.5.2.7.1.3	2	One or the other is Mandatory						
16	Geometric Vertical Rate	2.2.4.5.2.2 2.2.4.5.2.3 2.2.4.5.2.7.1.3	2							
17	UTC 1 PPS Timing	2.2.4.5.2.8	2	If input not directly accessible, a means to verify timing must be demonstrated						
18	Emitter Category	2.2.4.5.4.1	60	M	M	M	M	M	M	M
19	Call Sign / Flight ID	2.2.4.5.4.2	60	M	M	M	M	M	O	O
20	Emergency / Priority Status Selection	2.2.4.5.4.4	60	M	M	M	M	M	O	n/a
21	SIL	2.2.4.5.4.6	60	M	M	M	M	M	M	M
22	NACp	2.2.4.5.4.9	2	M	M	M	M	M	M	M
23	NACv	2.2.4.5.4.10	2	M	M	M	M	M	n/a	n/a
24	NICbaro	2.2.4.5.4.11	60	Can be internally “hard coded”		M	M	M	n/a	n/a
25	CDTI Traffic Display Capability	2.2.4.5.4.12.1	60	M	M	M	M	M	n/a	n/a
26	TCAS Installed and Operational	2.2.4.5.4.12.2	60	M	M	M	M	M	n/a	n/a
27	TCAS/ACAS Resolution Advisory Flag	2.2.4.5.4.13.1	60	Required only if ADS-B transmitter is intended for installation with TCAS/ACAS; otherwise can be “hard coded”						
28	IDENT Selection	2.2.4.5.4.13.2	60	M	M	M	M	M	M	n/a
29	“Receiving ATC Services” Flag	2.2.4.5.4.13.3	60	M	M	M	M	M	M	n/a
30	“True/Magnetic Heading” Flag	2.2.4.5.4.14	60	n/a	n/a	O	M	M	M	n/a
31	Heading / Track Indicator	2.2.4.5.6.1.2	60	n/a	n/a	O	M	M	n/a	n/a
32	Target Source Indicator (Horizontal)	2.2.4.5.6.1.4	60	n/a	n/a	O	M	M	n/a	n/a
33	Horizontal Mode Indicator (Horizontal)	2.2.4.5.6.1.5	60	n/a	n/a	O	M	M	n/a	n/a
34	Target Heading or Track Angle	2.2.4.5.6.1.7	60	n/a	n/a	O	M	M	n/a	n/a
35	Target Altitude Type	2.2.4.5.6.2.2	60	n/a	n/a	O	M	M	n/a	n/a
36	Target Source Indicator (Vertical)	2.2.4.5.6.2.4	60	n/a	n/a	O	M	M	n/a	n/a
37	Mode Indicator (Vertical)	2.2.4.5.6.2.5	60	n/a	n/a	O	M	M	n/a	n/a
38	Target Altitude Capability	2.2.4.5.6.2.6	60	n/a	n/a	O	M	M	n/a	n/a
39	Target Altitude	2.2.4.5.6.2.7	60	n/a	n/a	O	M	M	n/a	n/a
40	Radio Altitude	2.2.4.5.2.5.1	2	O	O	O	O	O	n/a	n/a

O = Optional M = Mandatory

2.2.7.2 Time Registration and Latency

This subparagraph contains requirements imposed on the ADS-B transmitter relative to two parameters. The first relates to the obligation of the transmitter to ensure position data in each ADS-B message relates to a standard *time of applicability*. The second relates to the obligation of the transmitter to reflect new ADS-B message data available at the transmitter input into the transmitted ADS-B message itself. This requirement is expressed as a *cutoff time* by which any updated data presented to the UAT transmitter should be reflected in the message output. Rules for time of applicability and cutoff time vary depending on the quality of SV data being transmitted and whether the transmitter is in the UTC Coupled state. The *Precision* or *Non-Precision* condition for reporting SV data is determined according to the criteria below:

a. Precision condition is in effect when:

   1. the “NACp” value is “10” or “11”, or, if “NACp” is not available, then

   2. the “NIC” value is “9,” “10” or “11”

b. Otherwise, the Non-Precision condition is in effect.

2.2.7.2.1 Requirements when in Non-Precision Condition and UTC Coupled

a. At the time of the ADS-B Message transmission, position information encoded in the “LATITUDE,” “LONGITUDE,” and “ALTITUDE” fields **shall** be applicable as of the start of the current 1 second UTC Epoch.

b. Any updated ADS-B Message fields, other than “LATITUDE,” “LONGITUDE” or “ALTITUDE,” that are provided at the ADS-B equipment input interface at least 200 milliseconds prior to the time of a scheduled ADS-B Message transmission that involves those fields, **shall** be reflected in the transmitted message.

Notes:

1. *Specifically, any extrapolation of position performed should be to the start of the 1-second UTC Epoch and not the time of transmission.*

2. *Velocity information cannot be extrapolated and may therefore have additional ADS-B imposed latency.*

2.2.7.2.2 Requirements When in Precision Condition and UTC Coupled

a. At the time of the ADS-B message transmission, the position information encoded in the “LATITUDE,” “LONGITUDE,” and “ALTITUDE” fields **shall** be applicable as of the start of the current 0.2 second UTC Epoch.

b. Any updated ADS-B Message fields, other than “LATITUDE,” “LONGITUDE” or “ALTITUDE,” that are provided at the ADS-B equipment input interface at least 200 milliseconds prior to the time of a scheduled ADS-B Message transmission that involves those fields, **shall** be reflected in the transmitted message.

Notes:

1. *Specifically, any extrapolation of position performed should be to the start of the 0.2 second UTC Epoch and not the time of transmission.*

2. *Operation in this condition assumes a GPS/GNSS sensor output rate of 5 Hz or greater is available to the ADS-B transmitter.*

2.2.7.2.3 Requirements when Non-UTC Coupled

a. At the time of ADS-B message transmission, each most recent ADS-B message field provided to the transmitter within the previous 2.0 seconds **shall** be reflected in the subsequent transmitted message containing that message field.

b. No extrapolation of position **shall** be performed in this condition.

2.2.7.2.4 Data Timeout

At the Time of Applicability for the ADS-B message transmission, any ADS-B message fields without an update provided to the transmitter within the Data Lifetime parameter (in seconds) of Table 2.2.7.1 **shall** be encoded as "data unavailable" in the subsequent transmitted message containing that message field.

2.2.8 Receiver Characteristics

2.2.8.1 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 2.2.8.1.

a. Full receiver and message processing function diversity:

   (see Figure 2.2.8.1, part a.)

   There are two receiver input channels, each with its own receiver front end, message synchronization, bit demodulation, and FEC decoding. All Successful Message Receptions from both channels **shall** be provided to the Report Assembly function. In the event both channels result in Successful Message Reception of identical messages, a single copy of this message may be provided.

b. Other diversity techniques. Other diversity implementations may be used. Any implementation must demonstrate equivalent or better performance to (a) above.

c. Receiving antenna switching:

   (see Figure 2.2.8.1, part b.)

   A single receiver input channel, consisting of receiver RF front end, message synchronization, bit demodulation and FEC decoding, is internally connected alternately and periodically, on the UTC second, between the top and bottom antennas. If this method is implemented, switching **shall** occur such that:

   1. Bottom and top antennas are alternated each second, AND

   2. No more than a single Long type ADS-B message arriving at the receiver at the beginning of the 1-second UTC Epoch is lost.

Note: *The purpose of this requirement is to place an upper bound on the time to switch antennas.*

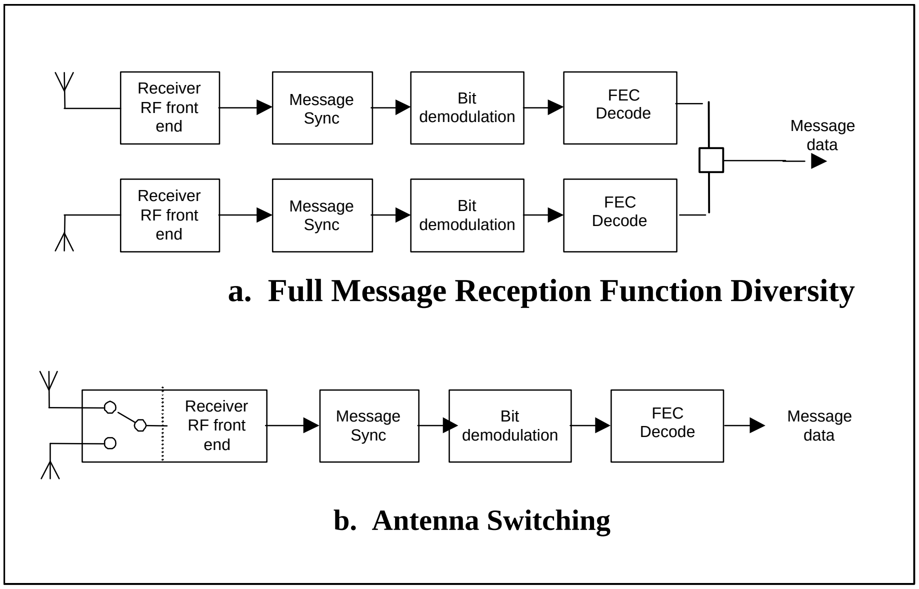

Figure 2.2.8.1: ADS-B Receiving Architectures.

2.2.8.2 Receiver Performance

2.2.8.2.1 Receiver Sensitivity

2.2.8.2.1.1 Long ADS-B Message is Desired Signal

A desired signal level of –93 dBm applied at the antenna end of the feedline **shall** produce a rate of Successful Message Reception of 90% or better under the following simultaneous conditions:

a. The desired signal is subject to the maximum permitted signal frequency offset plus air-to-air Doppler at 1200 knots closure/opening.

b. The desired signal is subject to the maximum modulation distortion allowed in subparagraph 2.2.2.4.

Note: *This also ensures that the Basic ADS-B Message will be received at the same desired signal level.*

2.2.8.2.1.2 Ground Uplink Message is Desired Signal

A desired signal level of –91 dBm applied at the antenna end of the feedline **shall** produce a rate of Successful Message Reception of 90% or better under the following simultaneous conditions:

a. The desired signal is subject to the maximum permitted signal frequency offset plus ground-to-air Doppler at 600 knots closure/opening.

b. The desired signal is subject to the maximum modulation distortion allowed in subparagraph 2.2.2.4.

Note: *This requirement ensures the baud rate accuracy supporting demodulation in the UAT equipment is adequate to properly receive the longer Ground Uplink message (assuming that the baud rate accuracy of the ground transmitter is 2 PPM).*

2.2.8.2.2 Receiver Desired Signal Dynamic Range

The receiver **shall** achieve a Successful Message Reception rate of 99% or better when the desired signal level is between –90 dBm and –10 dBm at the antenna in the absence of any interfering signals.

Notes:

1. *The value of –10 dBm represents 120-foot separation from an A3 transmitter at maximum allowed power.*

2. *Certain installations that rely on over-air reception of the own-ship transmission to meet the requirements of subparagraph 2.2.6.3 may need to achieve Successful Message Reception at significantly higher levels than –10 dBm.*

2.2.8.2.3 Receiver Selectivity

UPSAT INPUT

The receiver **shall** provide the following minimum signal rejection ratios as a function of frequency offset as listed in Table 2.2.8.2.3.

Table 2.2.8.2.3: Selectivity Rejection Ratios

Frequency Offset from Center (+/-)	**Minimum Rejection Ratio (Undesired/Desired level in dB)**	
	Equipment Class A0, A1L, A1H, A2	Equipment Class A3
1.0 MHz	[15] measured 13 & 18 at room temperature	[??]
2.0 MHz	52	[??]
10.0 MHz	67	[??]

Notes:

1. *The undesired signal used is an un-modulated carrier applied at the frequency offset.*

2. *This requirement establishes the receiver's rejection of off channel energy.*

2.2.8.2.4 Receiver Tolerance to Pulsed Interference

The receiver **shall** be capable of receiving messages in the presence of interference from on channel and off channel sources of pulse interference. The receiver **shall** be tolerant to pulse interference from TACAN/DME. The UAT receiver may experience pulsed interference from TACAN/DME channels operating in the 978 MHz to 1215 MHz frequency range. The UAT receiver must also be tolerant of pulsed interference from other L-Band systems operating and located on the aircraft. These may include 1030 MHz ATCRBS/Mode S interrogation signals from on-board TCAS and 1090 MHz ATCRBS/Mode S reply signals from on-board ATCRBS/Mode S Transponders. The receiver **shall** meet the reception probability dictated under the following conditions:

a. For all equipment classes:

   The receiver **shall** be capable of achieving 99% reception probability of ADS-B messages when the desired signal level is between –90 dBm and –10 dBm when subjected to TACAN/DME interference under the following conditions: TACAN/DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at either 12 or 30 microseconds pulse spacing at a level of –30 dBm for any 1 MHz channel frequency between 980 MHz an 1215 MHz inclusive.

b. For the A0, A1L, A1H, and A2 equipment classes:

   The receiver **shall** be capable of achieving 90% reception probability of ADS-B messages when the desired signal level is between –88 dBm and –10 dBm when subjected to TACAN/DME interference under the following conditions: TACAN/DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –53 dBm and a frequency of 979 MHz.

c. For the A3 equipment class:

   The receiver **shall** be capable of achieving 90% reception probability of ADS-B messages when the desired signal level is between –88 dBm and –10 dBm when subjected to TACAN/DME interference under the following conditions: TACAN/DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –42 dBm and a frequency of 979 MHz.

d. Following a 21 microsecond pulse at a level of 0 dBm and at a frequency of 1090 MHz, the receiver **shall** return to within 3 dB of normal sensitivity level within 12 microseconds.

2.2.8.2.5 Receiver Tolerance to Overlapping ADS-B Messages (Self Interference)

A Successful Message Reception rate of 90% or better, for the stronger of two overlapping desired messages, **shall** result when the level of the stronger message is no weaker than -80 dBm and the stronger message is at least ***X*** dB above the weaker message, when the stronger message and weaker message are aligned in time.

Where the value of ***X*** is:

4 dB for Equipment Classes A0, A1L, A1H, and A2

9 dB for Equipment Class A3

Notes:

1. *The different values across equipment classes reflect the fact that Class A3 receivers will utilize a narrow filter that degrades demodulation performance slightly in order to gain added rejection from adjacent channel DME ground stations.*

2. *Signal values ensure both the desired and undesired signal levels are above the noise floor.*

2.2.8.3 Receiver Message Processing

2.2.8.3.1 Criteria for Successful Message Reception

2.2.8.3.1.1 ADS-B Messages

The receiver **shall** declare Successful Message Receipt for an ADS-B message when there are NO uncorrected errors indicated by the RS decoding process. The decoding process **shall** use hard decision decoding with no erasures allowed.

Notes:

1. *Message format (Basic versus Long ADS-B) can be ascertained by attempting to decode both forms of the RS block, if necessary.*

2. *Appendix M provides the analytic determination of the Undetected Message Error Rate (UMER) achieved though use of the RS coding. Due to the straightforward calculation of the UMER and the fact that the UMER is quite low, no explicit requirement/test is needed for a "False Message Reception Rate" test.*

2.2.8.3.1.2 Ground Uplink Messages

The receiver **shall** determine Successful Message Receipt for a Ground Uplink message according to the following procedure:

a. Each de-interleaved RS block of the Ground Uplink message **shall** be individually examined for errors. Each RS block **shall** be declared as valid only if it contains NO uncorrected error after RS decoding. The decoding process **shall** use hard decision decoding with no erasures allowed.

b. Successful Message reception **shall** be declared for a Ground Uplink message when all six constituent RS blocks are declared valid from (a) above.

Note: *Appendix M provides the analytic determination of the Undetected Message Error Rate achieved though use of the RS coding. Due to the straightforward calculation of the UMER and the fact that the UMER is quite low, no explicit requirement/test is needed for a "False Message Reception Rate" test.*

2.2.8.3.2 Receiver Discrimination Between ADS-B and Ground Uplink Message Types

The receiver **shall** determine the message type by means of the correlation between the received bits, and the synchronization sequences given in subparagraphs 2.2.3.1.1 and 2.2.3.2.1.

Note: *Specifically, the receiver should not attempt to distinguish ADS-B messages from Ground Uplink messages by their position in the UAT frame.*

2.2.8.3.3 Receiver Processing of ADS-B Synchronization "Trigger"

Receivers **shall** meet the following message processing requirements:

a. When an initial ADS-B trigger occurs (no message decode in progress), the Message Reception process associated with this trigger **shall** be completed regardless of other trigger activity subsequently detected.

b. A second, subsequent ADS-B trigger event that occurs during the Message Reception process of an initial ADS-B trigger event **shall** also be completed regardless of other trigger activity subsequently detected.

c. A third ADS-B trigger event that occurs during the simultaneous decoding of an initial and second ADS-B trigger **shall** also be completed regardless of other trigger activity subsequently detected.

Notes:

1. *Detection of the ADS-B synchronization sequence is referred to as a "trigger."*

2. *These requirements ensure that the receiver "re-trigger" procedure does not abandon the initial trigger when a close match to the sync pattern appears in the payload, and that the transmitter need not preclude the sync pattern from occurring in the payload.*

3. *From simulation, this three-level decoding depth also assures that — in the highest self interference environments — the receiver will be >99.5% efficient in decoding of all ADS-B messages that appear at the receiver with an adequate SIR for Successful Message Reception.*

4. *See Appendix H for one potential method to implement a "re-trigger" capability of the synchronization mechanism, and for a recommended synchronization threshold value for ADS-B.*

5. *During decoding of an ADS-B trigger, it is acceptable for the receiver to be "locked out" to Ground Uplink triggers.*

6. *In the case of "full receiver diversity" (subparagraph 2.2.8.1 a.), the requirements of this subparagraph apply to each receiver channel individually.*

2.2.8.3.4 Receiver Processing of Ground Uplink Synchronization "Trigger"

Receivers **shall** meet the following message processing requirements:

a. When an initial Ground Uplink trigger occurs (no message decode in progress), the decode process associated with this trigger **shall** be completed regardless of other trigger activity subsequently detected.

b. A second, subsequent Ground Uplink trigger event that occurs during the decode process of an initial Ground Uplink trigger event **shall** also be completed regardless of other trigger activity subsequently detected.

***Notes*:**

1. *This two-level decoding depth assures that a strong Ground Uplink message will be decoded when a distant (>200 NM) station on the preceding time slot triggers the receiver. This minimizes planning constraints when assigning slot resources to ground stations.*

2. *See Appendix H for one potential method to implement a "re-trigger" capability of the synchronization mechanism.*

3. *During reception of a Ground Uplink message, it is acceptable for the receiver to be "locked out" to ADS-B triggers.*

2.2.8.3.5 Receiver Time of Message Receipt

The receiver **shall** declare a Time of Message Receipt (TOMR) and include this as part of the report issued to the on-board application systems. The TOMR value **shall** be reported to within the parameters listed below:

a. Range of at least 25 seconds expressed as seconds since GPS midnight modulo the range.

b. Resolution of 100 nanoseconds or less.

c. Accuracy of +/- 500 nanoseconds of the actual time of receipt for UAT equipment using either an internal, or external UTC coupled time source.

d. The reported TOMR will be equal to the following quantity: seconds since the previous UTC midnight modulo the specified TOMR range.

Note: *TOMR is required to support ADS-B Time of Applicability range validation by a receiving application. See Appendix I for a discussion of UAT Timing Considerations.*

2.2.9 Report Assembly Requirements

Each Successful Message Reception **shall** result in report assembly.

Note: Exemplary report formats are presented in Appendix J.

2.2.9.1 Report Assembly on Receipt of ADS-B Message

Reports **shall** contain the following information:

a. All elements of the received message payload applicable to the ADS-B report type with range and accuracy of each payload field preserved.

b. The Time of Message Receipt value measured by the receiver.

Note: *Time of Applicability may be derived by the receiving application from the TOMR.*

2.2.9.2 Report Assembly on Receipt of Ground Uplink Message

Reports **shall** contain the following information:

a. The 432 byte received message payload unaltered.

b. The Time of Message Receipt value measured by the receiver.

Note: *Time of Applicability may be derived by the receiving application from the TOMR.*

2.2.10 Receiver Subsystem Capacity and Throughput Requirements

The ADS-B receiving subsystem **shall** process Successful Message Receptions and make them available at the output interface as specified in the subparagraphs below.

2.2.10.1 Fundamental Principals of Report Assembly

Figure 2.2.10.1 illustrates the general data flow of ADS-B Messages and Reports for the purposes of establishing the baseline requirements for Report Assembly.

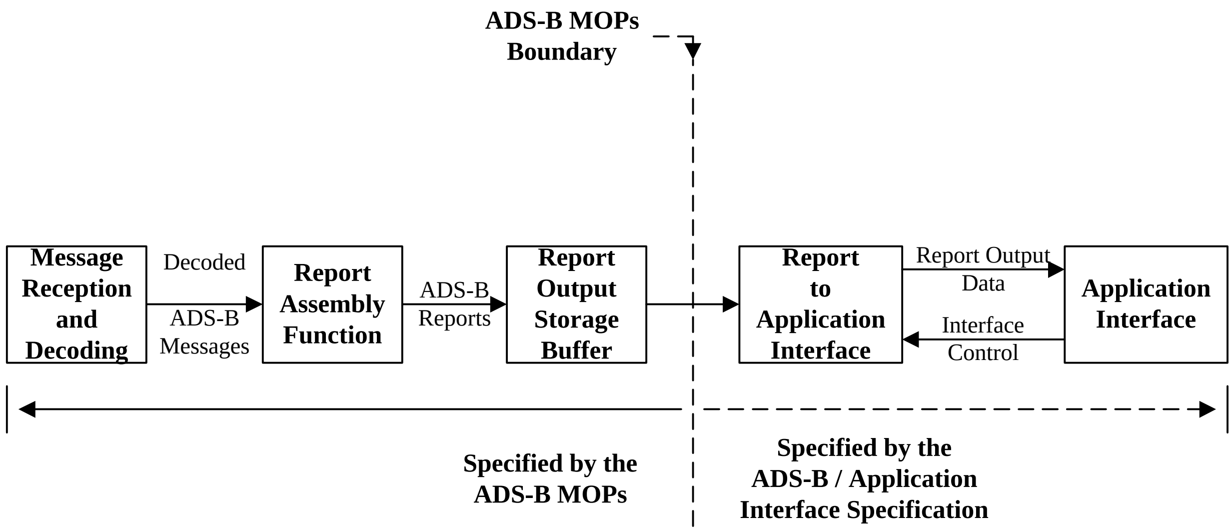

Figure 2.2.10.1: ADS-B Message And Report General Data Flow

a. **Message Reception and Decoding** -- The primary function of the Message Reception and Decoding function is to deliver all Successful Message Receptions to the Report Assembly Function.

b. **Report Assembly Function** -- The Report Assembly Function receives all Successful Message Receptions from the Message Reception and Decoding and structures Reports for delivery to the Report Output Storage Buffer.

Note: *It is important to note that the specification of requirements within this document is considered complete once the 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.*

c. **<u>Report Output Storage Buffer</u>** -- The primary purpose of the Report Output Storage Buffer is to store and maintain all Reports such that the Reports are available for extraction by the Application Interface upon demand or as needed.

<u>Note:</u> *It is assumed that once the Report is in the Report Output Storage Buffer, no appreciable additional latency is imposed.*

d. **<u>Application Interface</u>** -- 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.

2.2.10.2 Capacity for Successful Message Reception

Receiving subsystems **shall** demonstrate the ability to perform Successful Message Reception at the message input rates specified in Table 2.2.10.2.

<u>Table 2.2.10.2:</u> Message-to-Completed Report Assembly Throughput Requirements

Equipment Class of ADS-B Receiving Subsystem	Measurement Interval	Required Number of Input Messages	
		Ground Uplink	Long ADS-B
A0, A1L	1 second	32	600
	100 milliseconds	N/A	100
A1H, A2, A3	1 second	32	700
	100 milliseconds	N/A	120

2.2.10.3 Applicable Messages

Applicable Messages are defined as those requiring Report Assembly. Successful Messages are deemed to be Applicable Messages according to the criteria below:

a. For Successful Message Reception of ADS-B messages one of the following two criteria **shall** apply:

1. All Successful Message Receptions, OR

2. As a minimum, only those Successful Message Receptions from targets within the range criteria from Table 2.2.10.3A.

3. Should the number of targets from which a Successful Message is received exceed the values in Table 2.2.10.3A, the ADS-B UAT equipment may discard those messages received from targets at the greatest distance from Ownship. Any discarded reports **shall** be at greater range than those that are reported.

Table 2.2.10.3A: Range Criteria for ADS-B Messages

Equipment Class	Minimum Range from Ownship (NM)	Number of Targets from which a Successful Message is received within Minimum Range
A0	15	250
A1L	30	300
A1H/A2	60	500
A3	135	650

b. For Successful Message Reception of Ground Uplink messages, one of the following two criteria shall apply:

1. All Successful Message Receptions, OR

2. Only those Successful Message Receptions from ground stations within the range criteria from Table 2.2.10.3B.

Table 2.2.10.3B: Range Criteria for Ground Uplink Messages

Equipment Class	Minimum Number of Ground Uplink Reports Required (per second)
A0	16 closest to own-ship
A1L	16 closest to own-ship
A1H/A2	16 closest to own-ship
A3	16 closest to own-ship

2.2.10.4 Message Reception-to-Report Completion Time

All ADS-B Applicable Messages **shall** be output from the Report Assembly Function within 200 milliseconds of message input.

All Ground Uplink Applicable Messages **shall** be output from the Report Assembly Function within 500 milliseconds of message input.

2.2.11 Special Requirements for Transceiver Implementations

2.2.11.1 Transmit-Receive Turnaround Time

A transceiver **shall** be capable of switching from transmission to reception within 2 milliseconds.

Note: *Transmit to receive switching time is defined as the time between the optimum sampling point of the last information bit of one transmit message and the optimum sampling point of the first bit of the synchronization sequence of the subsequent receive message.*

2.2.11.2 Receive-Transmit Turnaround Time

A transceiver **shall** be capable of switching from reception to transmission within 2 milliseconds.

Note: *Receive to transmit switching time is defined as the time between the optimum sampling point of the last information bit of one receive message and the optimum sampling point of the first bit of the synchronization sequence of the subsequent transmit message.*

2.2.12 Response to Mutual Suppression Pulses

UAT equipment **shall not** provide suppression signals.

Note: *Adequate compatibility to other systems is achieved because of the power levels, frequency separation and duty factor of UAT transmissions without providing suppression signals.*

UAT equipment **shall not** receive suppression signals.

Note: *Adequate compatibility from other on-board systems is provided by the requirement of subparagraph 2.2.8.2.4.*

2.2.13 Self Test and Monitors

2.2.13.1 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.

2.2.13.2 Broadcast Monitoring

A monitor **shall** be provided to verify that ADS-B message transmissions are generated per the schedule defined in subparagraph 2.2.6.1. If any of the ADS-B message types for which the equipment is certified is not transmitted, then the equipment **shall** be considered as failed and the appropriate "Fail/Warn" indicators **shall** be set to the "Fail/Warn" state.

2.2.13.3 Address Verification

The ADS-B transmission device **shall** declare a device failure in the event that it's own ICAO 24-bit Address (if required to have a ICAO 24 bit address) is set to all "ZEROs" or all "ONEs."

2.2.13.4 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, then the receiving device **shall** be considered as failed and the appropriate "Fail/Warn" indicators **shall** be set to the "Fail/Warn" state.

2.2.13.5 Failure Annunciation

2.2.13.5.1 ADS-B Transmission Device Failure Annunciation

An output **shall** be provided to indicate the validity/non-validity of the ADS-B transmission device. Failure to generate ADS-B messages at a nominal rate, a failure detected by self-test or the monitoring function, or failure of the address verification **shall** cause the output to assume the invalid state. Momentary power interrupts **shall** not cause the output to assume the invalid state. The status of the ADS-B transmission device **shall** be enunciated to the flight crew where applicable.

2.2.13.5.2 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. 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.

2.2.13.5.3 Co-Located ADS-B Transmission and Receiving Device Failure Annunciation

In installations where the ADS-B transmission and receiving functions are implemented in a common unit, it **shall** be permissible to use a single Fail/Warn output that is used in common to satisfy the requirements of subparagraphs 3.XX-TBD. Otherwise, the Fail/Warn mechanisms for the ADS-B transmission function and the ADS-B receiving function **shall** be independent.

2.2.14 Antenna System

Antennas meeting the requirements of TSO-C66, TSO-C74, or TSO-C112 are acceptable. Separate antenna for receiving and transmitting are not required.

See Appendix E for further reference to antenna.

2.2.14.1 Polarization

The antenna **shall** be predominantly vertically polarized.

2.2.14.2 Antenna Voltage Standing Wave Ratio (VSWR)

The Voltage Standing Wave Ratio (VSWR) produced on the antenna transmission line by the antenna **shall** not exceed 1.7:1 at 978 MHz when the antenna is mounted at the center of a 1.2 meter (4 foot) diameter (or larger) flat circular ground plane. The transmission line impedance **shall** be that as specified by the equipment manufacturer.

2.2.15 Interfaces

2.2.15.1 ADS-B Transmitting Device Interfaces

2.2.15.1.1 ADS-B Transmitting Device Input Interfaces

Data delivery mechanisms **shall** ensure that each data parameter is provided to the input function of the ADS-B Transmitting device at sufficient update rates to support the ADS-B Message Update Rates provided in subparagraph 2.2.6.1.

2.2.15.1.1.1 Discrete Input Interfaces

Appropriate discrete inputs may be used to provide the ADS-B Transmitting device with configuration and control information. When implemented, all discrete inputs **shall** provide appropriate diode isolation to prevent sneak current paths.

2.2.15.1.1.2 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 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 Transmitting device control and message generation functions.

2.2.15.1.1.3 Processing Efficiency

The ADS-B Transmitting 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 message generation function to support the rates identified in subparagraph 2.2.6.1.

2.2.15.1.2 ADS-B Transmitting Device Output Interfaces

2.2.15.1.2.1 Discrete Output Interfaces

Appropriate discrete outputs may be used by the ADS-B Transmitting 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.

2.2.15.1.2.2 Digital Communication Output Interfaces

Appropriate Avionics Digital Communication output interfaces **shall** be implemented by the ADS-B Transmitting 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.

2.2.15.2 ADS-B Receiving Device Interfaces

2.2.15.2.1 ADS-B Receiving Device Input Interfaces

2.2.15.2.1.1 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.

2.2.15.2.1.2 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.

2.2.15.2.1.3 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.

2.2.15.2.2 ADS-B Receiving Device Output Interfaces

2.2.15.2.2.1 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.

2.2.15.2.2.2 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.

2.2.16 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.*

2.2.17 Compatibility with Other Systems

2.2.17.1 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.

2.2.17.2 Compatibility with GPS Receivers

The ADS-B transmitting and/or receiving equipment **shall** not compromise the operation of a co-located proximate GPS receiver.

2.2.17.3 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.