RTCA Special Committee 186, Working Group 3

ADS-B 1090ES MOPS Maintenance

Meeting #27

United Airlines World Headquarters, Elk Grove Township, IL
12 May – 15 May 2009

Revision to Required Changes to 1090 ES MOPS (except Appendix P) to Support Inclusion of Medium Power, Non-diversity Classes

Kurt Schueler
Garmin International

Summary

This Working Paper is in response to Action Item 26-12 and revises 1090-WP26-11 by removing references to "Example operations" from the 1090 ES MOPS which were originally taken from DO-242A. The primary purpose of the working paper is a summary of changes required to include medium power, non-diversity classes A1S and B1S to all sections and appendices of the 1090 ES MOPS *except* Appendix P. Changes to Appendix P are covered by a separate action item.

1 Introduction

This Working Paper is in response to Action Item 26-12 arising from SC-186 WG #3 Meeting #26/EUROCAE WG-51 SG-1 Meeting #3. The primary purpose is to detail changes to the 1090 ES MOPS that are required to add medium power, non-diversity classes to the existing classes in the MOPS. This paper represents a revision to 1090-WP26-11 by removing references to "Example operations" from the 1090 ES MOPS which were originally taken from DO-242A.

The new classes, A1S and B1S, are equivalent to the existing A1 and B1 classes, save for being single antenna. The need for the new classes arises from the ADS-B Aviation Rulemaking Committee to the Federal Aviation Administration recommendations regarding the antenna diversity and power requirements of the ADS-B OUT NPRM.

The list of changes is for RTCA/DO-260A including Change 1 and Change 2. The addition of new classes also affects changes proposed in 1090-WP23-03R1, and those effects are addressed. Throughout this WP, changes to the existing MOPS are highlighted. Changes that have been presented and agreed to in past revisions of this paper are highlighted in yellow. New changes are highlighted in pink.

2 Volume 1 Changes

2.1 Section 1 Changes

In Section 1.2.4.3, remove words that tie classes to specific applications:

…
The transmitter power is based on the classification of the ADS-B equipment. For example, ADS-B class A0 equipment~~, which is intended to support only the "aid to visual acquisition" application,~~ may transmit at a lower power than class A3 equipment~~, which is capable of supporting the "flight path de-confliction planning" application~~.
…

The operating range of the Extended Squitter receiver is tailored to the classification of the equipment as well. Class A0 equipment~~, intended to support only the "aid to visual acquisition" application,~~ may have a less sensitive receiver and thus support a comparatively short operating range. Class A3 equipment~~, which is capable of supporting the "flight path de-confliction planning" operation,~~ requires a more sensitive receiver~~,~~ in order to receive ADS-B Messages from aircraft that are farther away.

2.2 Section 2.1 Changes

Changes in this section consist of adding definitions, descriptions and classifications for the new Classes. Many of the tables in this section correspond to tables in the ADS-B MASPS. Changes are:

1. *In section 2.1.11, add a definition of class A1S and B1S:*

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

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

antennas are abbreviated throughout this document as "A1." The only equipment difference between classes A1 and A1S is antenna diversity.

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

2. *Change title of Section 2.1.12 to delete reference to applications:*

2.1.12 Equipage Class ~~Application Coverage~~ Categories

3. *In section 2.1.12, add classes A1S and B1S to the table of equipment classes, remove 'Example Applications' and 'Comments' columns, delete reference to DO-242A Table 3-1, delete Note 2*:

Table 2-1: ADS-B Aircraft System Classes
~~(adapted from RTCA DO-242A, Table 3-1)~~

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

Notes:
1. See §3.3.1 for Antenna Diversity.
~~2. All ADS-B Class A, B0 and B1 systems are also intended to support the Air-to-Ground ATC Surveillance applications.~~

4. *In section 2.1.12.1, add classes A1S and B1S to the tables of Transmit Message Coverage by equipment class and remove 'Example Operation' column:*

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

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

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

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

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

5. *In section 2.1.12.2, add class A1S to the table of Transmit Message Coverage by equipment class, remove 'Example Operation' column, update 'Receiver Class' descriptions to be consistent with DO-242A (which doesn't assign VFR/IFR distinction):*

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

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

2.3 Section 2.2 Changes

Changes in this section are generally editorial, adding A1S and B1S where appropriate for the transmit power, receive sensitivity and bit declaration and confidence techniques.

1. *In section 2.2.2.1 (Mode S Transponder Based Transmitters), add classes A1S and B1S to the list of classes based on Mode S transponders with greater than or equal to 125 W peak output power levels:*

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

systems **shall** be based on Mode S transponders with RF Peak Output Power levels as specified in §2.2.2.1.1.3, or §2.2.2.1.1.4, respectively, for the class of equipment.

2. *In section 2.2.2.1.1.2 (Class A1 ADS-B Transponder Based Transmitter Power), revise section title and text to include Class A1S:*

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

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

3. *In section 2.2.2.1.1.5 (Class B ADS-B Transponder Based Transmitter Power), revise text to require 125 W minimum peak output power for Class B1S.*

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

4. *In section 2.2.3.3.1.4.6.1 (Event-Driven Message Scheduling Function), add Class A1S as optional class for TC message in the note.*

   Note: *This version of these MOPS does not define the message format for the broadcast of Trajectory Change information (§2.2.3.2.7.7). However it is anticipated that future versions of these MOPS will require the broadcast of Trajectory Change information for all Class A2 and Class A3 airborne systems and will be optional for Class A1S and A1 airborne systems. The following requirements for the Event-Driven Message Scheduling Function include provisions to accommodate the future addition of messages conveying Trajectory Change information (i.e., message TYPE=27).*

5. *In section 2.2.4.3.1.1 (In-Band Acceptance), table 2-79, add Class A1S with MTL less than or equal to -79 dBm.*

   Table 2-79: ADS-B Class "A" Equipment Receiver Sensitivity

EQUIPMENT CLASS	A0	A1S/A1	A2	A3
MTL	-72 dBm	-79 dBm	-79 dBm	-84 dBm

6. *In section 2.2.4.3.1.2 (Re-Triggerable Capability), add Class A1S to requirement for re-triggering capability.*

   ADS-B receivers having Equipment Class A1S, A1, A2 or A3 capability **shall** re-trigger if such receivers detect an ADS-B Message having a preamble that is at least 3 dB stronger than that of the message that is currently being processed.

7. *In section 2.2.4.4.2 (Enhanced Squitter Reception Technique Overview), add Class A1S to requirement to comply with test procedures of 2.4.4.4.*

   Class A1S, A1, A2 and A3 equipment **shall** demonstrate compliance with test procedures specified in §2.4.4.4 and its subparagraphs.

Note: *The full set of enhanced techniques are applicable to Class A2 and A3 receiving equipment. Class A1S and A1 receiving equipment requires only a subset of the enhanced reception capabilities, and this is reflected in the test procedures of §2.4.4.4 and its subparagraphs.*

8. *In section 2.2.4.5 (ADS-B Received Message Error Protection), add Class A1S to item c. requiring enhanced error correction techniques.*

   c. Error correction techniques for equipment classes A1S, A1, A2 and A3 are specified in §2.2.4.4.2.

9. *In table 2-82, add Class A1S to all reports that are required by Class A1.*

Table 2-82: ADS-B Report Type Coding

Coding	Report Type	Maximum Number of Bytes in Report
0000	Undefined Report Type or no Report Available	1
0001	State Vector Report for ALL Class "A" Equipment	48
0010	Mode-Status Report for Class "A1S" and "A1" Equipment	35
0011	ADS-B Target State Report for Class "A2" and "A3" Equipment (Optional for Class "A1S" and "A1" equipment)	22
0100	Air Reference Velocity Report for Class "A1S", "A1", "A2" and "A3" equipment	14
0101	Reserved for Trajectory Change Report for Class "A2" and "A3" equipment	
0110 through 1111	Not Assigned (Reserved for Future Assignment)	

10. *In section 2.2.9.1 (ADS-B Receiver Reporting Requirements for Class A Equipage) table 2-100, add Class A1S to Class A equipment reporting requirements, and fix typo in note 2, remove columns associating applications to specific classes and reports to specific applications, update 'Equipage Class' descriptions to be consistent with DO-242A (which doesn't assign VFR/IFR distinction).*

Table 2-100: ADS-B Class A Equipment Reporting Requirements

Equipage Class	ADS-B OUTPUT REPORTS REQUIRED (Note 1)
AO Minimum~~Basic VFR~~ Aircraft~~,~~ and Ground Vehicles	SV MS
A1S/A1 Basic ~~IFR~~ Aircraft and Ground Vehicles	SV MS ARV
A2 Enhanced ~~IFR~~ Aircraft Only (Note 2)	SV MS TS ARV
A3 Extended ~~Capability~~ Aircraft Only (Note 2)	SV MS TS ARV

Notes:
1. The report structure and contents are specified in §2.2.8.1 through §2.2.8.3, inclusive of the subparagraphs.
2. It is anticipated that future revisions of these MOPS will require that Equipage Class A2 and A3 systems will also be capable of generating Trajectory Change Reports.

11. *In section 2.2.9.1.1 (ADS-B State Vector Reports for Class A Equipage), add Class A1S.*

    Equipage Class A0, A1S, A1, A2 and A3 equipment **shall** provide State Vector Reports as indicated in §2.2.9.1. An example report format is showin in Table 2-81.

12. *In section 2.2.9.1.2 (ADS-B Mode Status Reports for Class A Equipage), add Class A1S.*

    Equipage Class A0, A1S, A1, A2 and A3 equipment **shall** provide Mode Status Reports as indicated in §2.2.9.1. An example report format is shown in Table 2-88.

13. *In section 2.2.9.1.3 (ADS-B Target State Reports for Class A Equipage), add Class A1S as class not required to provide report.*

    a. Equipage Class A0, A1S and A1 equipment are not required to provide Target State Reports.

14. *In section 2.2.9.1.4 (ADS-B Air Referenced Velocity Reports for Class A Equipage), add Class A1S to item b.*

    b. Equipage Class A1S, A1, A2 and A3 equipment **shall** generate an Air Referenced Velocity Report as indicated in §2.2.9.1. An example report format is shown in Table 2-96.

15. *In section 2.2.10.5 (Minimum Number of Participant Track Files), table 2-105, add Class A1S requiring at least 200 participant track files.*

Table 2-105: Minimum Participant Track File Capacity

Equipage Class of ADS-B Receiving Subsystem	Minimum Number of Participant Track Files
A0	100
A1S/A1	200
A2	400
A3	400

2.4 Section 2.3 Changes

Changes in this section are editorial, adding classes A1S and B1S as needed for changes in Section 2.2.

1. *In section 2.3.2.3.3 (Verification of Enhanced Squitter Reception Techniques), add Class A1S to list of classes for which test procedures apply.*

   The following test procedures apply to Class A1S, A1, A2 and A3 receivers that implement Enhanced Squitter Reception Techniques and are part of the TCAS Receiver.

2. *In the proposed change to section 2.3.2.4.3 (Verification of Re-Triggerable Capability) in 1090-WP23-03R1, add class A1S to the proposed table of success criteria.*

   Step 1: Re-Trigger Capability - Part 1
   Apply **Input** at the receiver input and verify that at least the reply ratio in the following table of the second valid ADS-B Messages are correctly decoded.

Receiver Class	Class A1S/A1	Class A2	Class A3
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93

3. *In the proposed addition of section 2.3.2.4.6.1 (Criteria for ADS-B Message Transmission Pulse Detection for Receivers not using Enhanced Reception Techniques) in 1090-WP23-03R1, add class A1S to the list of 'not applicable' equipage classes.*

   Note: *This test is not applicable to equipment which uses the enhanced reception techniques. That is, it is not applicable to equipage classes A1S, A1, A2 and A3. The enhanced preamble detection requirements for this equipment are tested in §2.3.2.4.6.2.*

4. *In section 2.3.2.4.8.1 (Combined Preamble and Data Block Tests with A/C Fruit), add Class A1S to steps 1 and 2, and title of table 2-114.*

   Step 1: Verification of Operation of Equipment Under Test
   Connect the Extended Squitter signal source and set the power level at the receiver input equal to the MTL limit required for the UUT equipment class:
   –79 dBm for A1S or A1 equipment class or,
   –79 dBm for A2 equipment class or,
   –84 dBm for A3 equipment class.

…

Step 2: Test with Three Mode A/C Fruit Overlaps
Set the Extended Squitter signal source as specified in Step 1. Set the power level of three Mode A/C fruit sources at the receiver input to the value corresponding to the UUT equipment class:
-71, -67 and –63 dBm for A1S, A1 or A2 equipment class or,
-76, -72 and –68 dBm for A3 equipment class.

…

Step 3: Determination of Success or Failure
Compare the results recorded above with the appropriate requirements in Table 2-114, Table 2-115 or Table 2-116.

Table 2-114: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – Class A1S and A1 Equipment

Number of Fruit	**3**
Minimum Probability	0.53
Max Undetected Errors	1

5. *In section 2.3.2.4.8.2 (Data Block Tests with Mode S Fruit), add Class A1S to step 1 and title of table 2-117.*

Step 1: Verification of Operation of Equipment Under Test
Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Step 3: Determination of Success or Failure
Compare the results recorded above with the appropriate requirements in Table 2-117, Table 2-118 or Table 2-119.
Table 2-117: Success Criteria for Data Block Tests with Mode S Fruit – Class A1S and A1 Equipment

Relative Power (S/I) dB	**0**	**+8**
Minimum Probability	0	0.99
Max Undetected Errors	1	1

6. *In section 2.3.2.4.8.3 (Re-Triggering Performance), add Class A1S to steps 1 and 2, and title of table 2-120.*

Step 1: Verification of Operation of Equipment Under Test
Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Step 2: Re-triggering Test with Varying Position Mode S Fruit
Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Table 2-120: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A1S and A1 Equipment

Relative Power, (S/I) dB	**+4**	**+12**
Minimum Probability	0.12	0.91
Max Undetected Errors	1	1

2.5 Section 2.4 Changes

Changes in this section are editorial, adding classes A1S and B1S as needed for changes in Section 2.2. It is assumed that requirement text will be removed from this section, so changes to that text are ignored.

1. *In section 2.4.2.1.1.2 (Verification of Class A1 ADS-B Transponder Based Transmitter Power), add Class A1S to section Title (and update TOC correspondingly).*

2.4.2.1.1.2 Verification of Class A1S and A1 ADS-B Transponder Based Transmitter Power (§2.2.2.1.1.2)

2. *In the proposed change to section 2.4.4.3.1.2 (Verification of Re-Triggerable Capability) in 1090-WP23-03R1, add class A1S to the proposed table of success criteria.*

Step 1: Re-Trigger Capability - Part 1
Apply **Input** at the receiver input and verify that at least the reply ratio in the following table of the second valid ADS-B Messages are correctly decoded.

Receiver Class	**Class A1S/A1**	**Class A2**	**Class A3**
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93
Minimum Probability, Step 1	0.49	0.93	0.93

3. *In section 2.4.4.3.3 (Verification of Dynamic Minimum Trigger Level), update note to add class A1S.*

   Note: *This test procedure is only applicable to equipment that do not use the enhanced reception techniques. That is, it is not applicable to equipage classes A1S, A1, A2 and A3..*

4. *In the proposed change to section 2.4.4.3.4.7.1 (Verification of Criteria for ADS-B Message Transmission Pulse Detection) in 1090-WP23-03R1, add class A1S to the list of 'not applicable' equipage classes.*

   Note: *This test is not applicable to equipment which uses the enhanced reception techniques. That is, it is not applicable to equipage classes A1S, A1, A2 and A3. The enhanced preamble detection requirements for this equipment are tested in §2.3.2.4.6.2.*

5. *In section 2.4.4.4.2.4 (Combined Preamble and Data Block Tests with Mode A/C Fruit), add class A1S to introduction, steps 1-4, and title of table 2-157.*

   … For A1S and A1 equipment class, the tests are limited to a maximum of three Mode A/C fruit overlaps.

   …

   Step 1: Verification of Operation of Equipment Under Test
   Connect the Extended Squitter signal source and set the power level at the receiver input equal to the MTL limit required for the UUT equipment class:
   –79 dBm for A1S or A1 equipment class or,
   –79 dBm for A2 equipment class or,
   –84 dBm for A3 equipment class.

   …

   Step 2: Test with One Mode A/C Fruit Overlap
   Set the Extended Squitter signal source as specified in Step 1. Set the power level of one Mode A/C fruit source at the receiver input to the value corresponding to the UUT equipment class:
   –67 dBm for A1S, A1 or A2 equipment class or,
   –72 dBm for A3 equipment class.

   …

   Step 3: Test with Two Mode A/C Fruit Overlaps
   Repeat Step 2 with two fruit overlaps set to the following power levels and record the results:
   -69 and –65 dBm for A1S, A1 or A2 equipment class or,
   -74 and –70 dBm for A3 equipment class.

   …

   Step 4: Test with Three Mode A/C Fruit Overlaps
   Repeat Step 2 with three fruit overlaps set to the following power levels and record the results:
   -71, -67 and –63 dBm for A1S, A1 or A2 equipment class or,
   -76, -72 and –68 dBm for A3 equipment class.

   …

   Table 2-157: Success Criteria for Preamble and Data Block Tests

with Mode A/C Fruit – Class A1S and A1 Equipment

Number of Fruit	**1**	**2**	**3**
Minimum Probability	0.89	0.64	0.52
Max Undetected Errors	1	1	1

6. *In section 2.4.4.4.2.5 (Data Block Tests with Mode S Fruit), add class A1S to step 1 and title of table 2-160.*

Step 1: Verification of Operation of Equipment Under Test
Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Table 2-160: Success Criteria for Data Block Tests with Mode S Fruit – Class A1S and A1 Equipment

Relative Power (S/I) dB	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**	**+8**	**+12**
Minimum Probability	0	0	0.02	0.12	0.56	0.71	0.94	0.95	0.99	0.99
Max Undetected Errors	1	1	1	1	1	1	1	1	1	1

7. *In section 2.4.4.4.2.6 (Re-Triggering Performance), add class A1S to steps 1-3, and titles of tables 2-163 and 2-166.*

Step 1: Verification of Operation of Equipment Under Test
Connect the Extended Squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Step 2: Re-triggering Test with Varying Position Mode S Fruit
Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Table 2-163: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – Class A1S and A1 Equipment

Relative Power, (S/I) dB	+4	+8	+12
Minimum Probability	0.12	0.70	0.91
Max Undetected Errors	1	1	1

…

Step 3: Re-triggering Test with Fixed Position Mode S Fruit Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:
–67 dBm for A1S, A1 or A2 equipment class or,
–72 dBm for A3 equipment class.

…

Table 2-166: Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – Class A1S and A1 Equipment

Relative Power, (S/I) dB	+4	+8	+12
Minimum Probability	0	0.49	0.87
Max Undetected Errors	1	1	1

8. *In section 2.4.9.1.3 (Verification of the ADS-B Target State Reports for Class A Equipage), update text to include class A1S. Assuming requirement text will be removed from test, change is only needed in measurement procedure.*

   Measurement Procedure:
   a. Equipage Class A0, A1S and A1 equipment are not required to comply with any of the test procedures in §2.4.8.3.

9. *In section 2.4.10.5 (Verification of the Minimum Number of Participant Track Files), add class A1S to A1 in Table 2-203.*

Table 2-203: Participant Track File Stimulus Requirements

Column (0)	1	2	3	4
Equipage Class of ADS-B Receiving Subsystem	**Range (NM) for ADS-B Receiving Class**	**Number of Participant Track Files Within Range**	**Extended Range (NM) for ADS-B Receiving Class (min -to- max)**	**Number of Participant Track Files Within Extended Range**
A0	10	100	10 -to- 15	50
A1S and A1	20	200	20 -to- 30	100
A2	40	400	40 -to- 60	200
A3	60	400	60 -to- 90	200

2.6 Section 3 Changes

Changes in this section are primarily editorial, reflecting changes to Section 2. The first change is a suggestion specifying Class A1S and B1S installations with equivalent coverage to bottom mounted antenna installations.

1. *In section 3.1.2, revise the second paragraph to 'decouple' classes from applications:*

   ~~All configurations of ADS-B transmitters may be used for VFR applications. IFR applications require transmission and/or reception of State Vector and Mode Status messages.~~ Different classes of equipment have different minimum message capability requirements. Transmitted message capability requirements for Class A and Class B transmitters are defined in §2.1.12.1. Some applications may require support for specific On-Condition Messages.

2. *In section 3.3.1 (General Considerations), add requirement that single antenna installations have performance equivalent to bottom mounted antenna.*

   Antenna gain and pattern characteristics are major contributors to the system data link performance. The location and number of antennas required for aircraft ADS-B systems is determined by the equipage class. Class A1, A2, and A3 equipment require antenna diversity and **shall** have transmitting and receiving capability on both the top and bottom of the aircraft. Class B1 equipment requires antenna diversity and **shall** have transmitting capability on both the top and bottom of the aircraft. Diverse use of the installed antennas **shall** comply with the requirements of §8.2.13.6 and may be demonstrated by analysis.

   Class A0, A1S, B0 and B1S antenna gain pattern performance **shall** be shown at least equivalent to that of a quarter-wave resonant antenna mounted on the fuselage bottom surface.

3. *In section 3.1.2, remove second paragraph*
4. *In section 3.3.4 (Antenna Gain Performance), add class A1S to row with Class A1 in Table 3-2.*

   Table 3-2: Minimum Ranges for Receiving Reliability

Equipage		Required Range (NM)
Class	**Type**	
A0	Minimum	10
A1S/A1	Basic	20
A2	Enhanced	40
A3	Extended	90*
A3+	Extended Desired	120*

5. *In section 3.3.4.5.3 (Dynamic Response), add class A1S to note.*

   Note: *Class A0 and A1S installations are not required to install multiple (e.g. top fuselage and bottom fuselage) antennas.*

6. *In section 3.3.4.6.1 (Verification of Transmit Pattern Gain), add class A1S to 125 W minimum ERP verification in steps 2 and 4.*

   Step 2: Measure the Output Power of the ADS-B Transmitting Subsystem or device

   …

For Class A1S, A1, A2, and A3 equipment, verify that the output power is at least 125 watts (i.e., 20.97 dBw, or 50.97 dBm). Log the measurement as P_out.

Step 4: Establish Measurement Reference #1

…

For Class A1S, A1, A2, and A3 equipment, verify that the ERP (see Equation 3) is at least 125 watts (i.e., 20.97 dBw, or 50.97 dBm). Log the measurement as ERP_dBw.

7. *In section 3.3.4.6.2 (Verification of Receiver Pattern Gain), add class A1S to classes A1, A2 and A3 in step 1.*

Step 1: Install ADS-B Transmission Capability

…

For Class A1S, A1, A2, and A3 Receiver installations, install a ADS-B Test Transmitting device having a minimum RF power of least 125 watts (i.e., 20.97dBw, or 50.97 dBm) ***plus*** 3 dB. If additional cabling or connectors are required to make the connection, then the added attenuation must be accounted for when applying the equations given in §3.3.4.6.1 in this procedure.

3 Volume 2 Changes

3.1 Appendix E Changes

Change consists of including Class A1S with Class A1 in the link budget range analysis.

Table E-1: Air-To-Air Link Budget Ranges for Equipage Classes

	Class	**A0**	**A1S/A1**	**A2**	**A3**
Basic Requirements	Transmitter power (dBm at antenna)	48.5 to 57	51 to 57	51 to 57	51 to 57
	Receiver MTL (dBm at antenna)	≤ -72	≤ -79	≤ -79	≤ -84
Transmitter power	dBm at antenna, worst case (minimum power)	48.5	51.0	51.0	51.0
Antenna gain, transmitter	dB	0	0	0	0
Antenna gain, receiver	dB	0	0	0	0
Received Power	dBm at antenna	-72.0	-79.0	-79.0	-84.0
MTL	dBm at antenna, worst case	-72.0	-79.0	-79.0	-84.0 (90%) - 87.0 (15%)
Link Budget Ranges	NM	14	38	38	67 (90%) 95 (15%)

Notes:

1. For Class A3 the receiver requirements have two parts, therefore two ranges are shown in this column. The 90% point represents the conventional MTL operating point. The 15% operating point at –87 dBm is required in §2.2.4.3.1.1. The 15% point provides for reliable tracking and meets the surveillance update rate requirements.

2. These link budget ranges were developed assuming a receiver duty factor of 0.9. However, other factors that will be present in practical installations were not considered. These other factors include better-than-worst-case transmitter power and receiver MTL, antenna gain

variations, and receptions below MTL. These factors may be expected to support operation with 95 percent of the user population at the ADS-B report update requirements specified in the MASPS, under realistic conditions at ranges as follow:
R = 10 NM for class A0 (single antenna installations assumed),
R = 34-40 NM for Class A1S (single antenna installations assumed),
R = 34-40 NM for Class A1 (top and bottom antenna installations assumed),
R = 60-67 NM for Class A2 (top and bottom antenna installations assumed), and
R = 120-134 NM for Class A3 (top and bottom antenna installations assumed).
These are power-limited ranges that apply in the absence of interference. See Appendix P for the estimated performance in an interference environment.

3.2 Appendix I Changes

In Appendix I.4.2.1 (Enhanced Bit and Confidence Declaration Overview), include class A1S with class A1 as being appropriate for use of the center sample technique for bit and confidence declaration.

> The following description of the center sample technique is intended to provide an example of processing performance needed to meet the requirements of Class A1S and A1 equipment. This description also serves as an introduction to the three more capable approaches. The center sample technique will not provide sufficient performance to meet requirements specified for Class A2 and A3 equipment in the test procedures of §2.4.4.4. The specified performance for these latter classes of equipment can only be met by an approach that performs equivalently to one of the multi-sample techniques.

3.3 Appendix L Changes

Consider adding error rate bound for class A1S.

The last row of Table L-1 applies directly to Class A3 equipment, and the first row applies to Class A0. Because of the higher MTL values in Classes A2, A1 and A1S, relative to A3, lower error rates are expected, but because of the statistical nature of the Monte Carlo technique, it was not practical to evaluate these cases directly. The summary that follows provides error rate bounds for these two classes.

Class A3, error rate is approximately 0.05 x (10^{-6}) per report
Class A2, error rate < 0.05 x (10^{-6}) per report
Class A1, error rate < 0.05 x (10^{-6}) per report
Class A1S, error rate < 0.05 x (10^{-6}) per report
Class A0, error rate is approximately 0.09 x (10^{-6}) per report.

3.4 Appendix P Changes

A separate action item exists to update Appendix P.