UAT-WP-9-01
10 December 2001

RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #9

Draft 7 of the Proposed Section 2.2

Presented by Chris Moody

SUMMARY
This is Draft 7 of the proposed Section 2.2. See the major changes that follow.

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UAT MOPS Section 2.2
3 December Draft

Changes relative to Draft 6 to produce Draft 7

- The concept of Ramp Up and Ramp Down has been moved from inclusion as part of message structure and instead now appears in the section on Transmitter Power. Ramping now appears as new transmitter power states
- Receiver Characteristics (2.2.8.) has been restructured slightly per Stan's suggestion at the Nov meeting. We start at the antenna with diversity requirements (2.2.8.1), then move on to requirements related to RF, IF and demod performance (2.2.8.2), then finally deal with receiver message processing (2.2.8.3) which are more digital and bit-oriented in nature.
- What now appears as Sect 2.2.7 (ADS-B Transmitter Data Characteristics) was moved from later in the doc so it will be with the transmitter-related functions.
- Summary of new organization:
  - Related to Tx functions   Sect 2.2.2 thru 2.2.7
  - Related to Rx functions   Sect 2.2.8 thru 2.2.10
  - General/misc   Sect 2.2.11 thru 2.2.17
- Agreed changes discussions from Nov not captured real time now included.
- New sections added based on 1090 MOPS
- All **shalls** are bolded for clarity. I propose we retain this until final editing in order to aid development of test procedures
- Numerous editorials

➢

Updated: Month day, year
RTCA/DO-???
Prepared by: RTCA, Inc.

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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 a transmitter-to-antenna transmission line of loss equal to the maximum for which the transmitting function is designed.

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

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

2.2.1.2 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 megabaud.

Notes:

1. *Baud = symbol per second. Each symbol represents one bit, thus making each bit period 0.96 microsecond.*

2. *Ground Uplink Messages will use the same modulation type.*

3. *Adherance 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 **shall** apply at the optimum sampling points for the bit interval.

Notes:

1. *Filtration of the transmitted signal (at base band and/or after frequency modulation), will be required to meet the spectral containment requirement of Section 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 μsec). 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 [590 kHz] when measured over an entire Long ADS-B message containing pseudorandom information. **Tom Mosher will recommend final number for Jan mtg**

Note*: This requirement accounts for baud rate offset.*

2.2.2.5 Transmitter Power Output

The UAT transmit function **shall** have 4 states, defined as follows (see Figure 2.2.2.5):

a. Inactive state: During the normal receive operation, the transmitter is in the Inactive state. RF output power at the antenna terminals **shall** not exceed -80 dBm when measured in a 1 MHz bandwidth centered on the transmission frequency.

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.*

b. Pre-Key state: The transmitter is being prepared to enter the Active state. The Pre-Key state **shall** have a duration of not to exceed [4] microseconds. During this state the RF output power at the antenna terminals **shall** remain at least [20] dB below the minimum power requirement for the appropriate equipment class per Table 2-1. **Tom Mosher to get back to WG for the January Meeting to resolve the previous bracketed items.**

c. Ramp Up state: The maximum time duration of the Ramp Up state **shall** be no more than 4 bit periods. Ramp up time is defined as the time between the transmitter power level at the end of the Pre-Key state until the minimum power defined for the Equipment Class in the active state is achieved.

d. Active state: The Active state spans the time during which the actual ADS-B message bits are transmitted. During this period RF output power at the antenna terminals **shall** comply with Table 2-2.

e. Ramp Down state: The maximum time duration of the Ramp Down state **shall** be no more than 4 bit periods. Ramp down time is defined as the time between the end of the Active state until the beginning of the Post-Key state.

***Note**: The Ramp Up and Ramp Down states are present to support spectral containment*

f. Post-Key state: The transmitter is transitioning from the Active to the Inactive states. The Post-Key state **shall** have a duration of not to exceed [4] microseconds. During this state the RF output power at the antenna terminals **shall** remain at least [20] dB below the minimum power requirement for the appropriate equipment class per Table 2-2. **Tom Mosher to get back to WG for the January Meeting to resolve the previous bracketed items.**

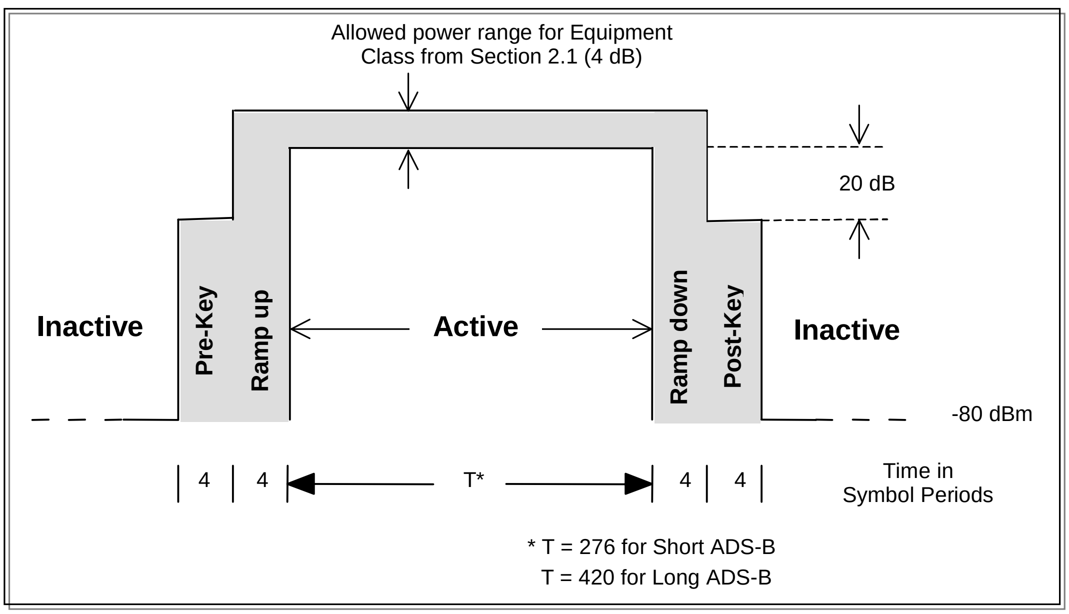


Figure 2.2.2.5 Time Domain Power Mask

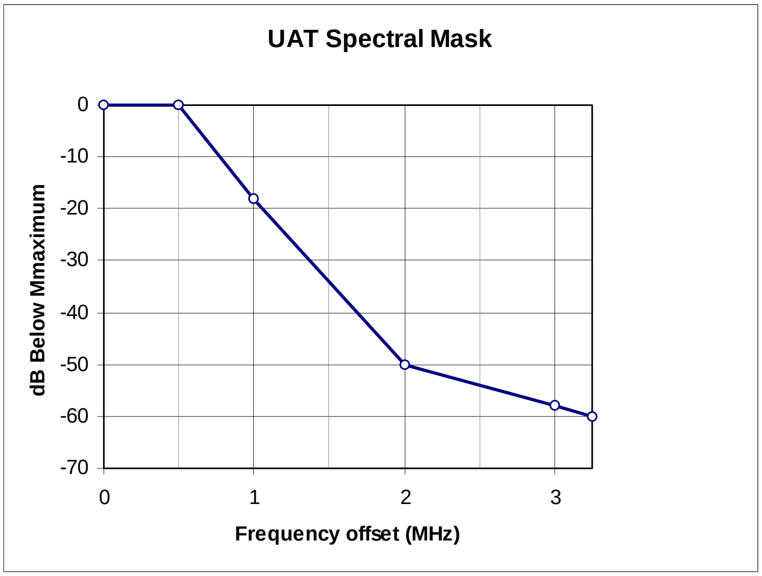
2.2.2.6 In Band Transmission Spectrum

The spectrum of a UAT transmission **shall** fall within the limits specified in Table 2.2.2.6 and Figure 2.2.2.6 below when measured in a 100 kHz bandwidth.

<u>Table 2.2.2.6</u>: UAT Transmit Spectrum

Frequency Offset From Center	Required Attenuation from Maximum (dB)
All frequencies in the range 0-0.5 MHz	0
1.0 MHz	18
All frequencies in the range 0.5 – 1.0 MHz	Based on linear* interpolation between these points
2.0 MHz	50
All frequencies in the range 1.0 – 2.0 MHz	Based on linear* interpolation between these points
3.25	60
All frequencies in the range 2.0 – 3.25 MHz	Based on linear* interpolation between these points

*based on amplitude in dB and a linear frequency scale



<u>Figure 2.2.2.6</u>: UAT Transmit Spectrum

<u>Note:</u> *This requirement extends to 250% of the "occupied bandwidth," where the occupied bandwidth has been determined to be 1.3 MHz.*

2.2.2.7 Out-of-Band Emissions

Out-of-Band emissions **shall** comply with applicable FCC regulations beyond 250% of the occupied bandwidth, that is, 3.25 MHz from the center frequency.

[100 kHz bw?]

2.2.3 Broadcast Message Characteristics

[Need to point reader to overview material in Section 1.0 to make clear where in frame each message type gets transmitted]

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 the subsections that follow.

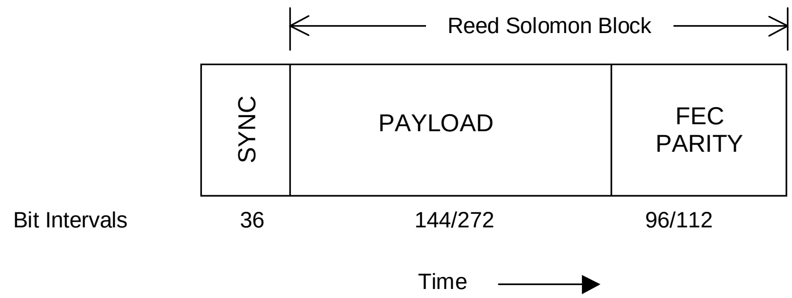


Figure 2.2.3.1: ADS-B Message Format

NOTE: Traffic Information Services-Broadcast (TIS-B) messages are identical to ADS-B messages in format—including use of the same synchronization pattern. TIS-B messages are therefore not defined separately

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 Section 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 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 (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 (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:

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

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

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

Notes*:*

1. *References for Forward Error Coding and the Galois Field are listed below:*

   a. *Peterson, W. W., and E. J. Weldon, Jr.,* Error-Correcting Codes, *2nd ed., MIT Press, Cambridge, MA, 1972.*

   b. *Michelson, A. M., and A. H. Levesque,* Error-Control Techniques for Digital Communication, *John Wiley & Sons, New York, NY, 1985.*

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 X 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 the subsections that follow.

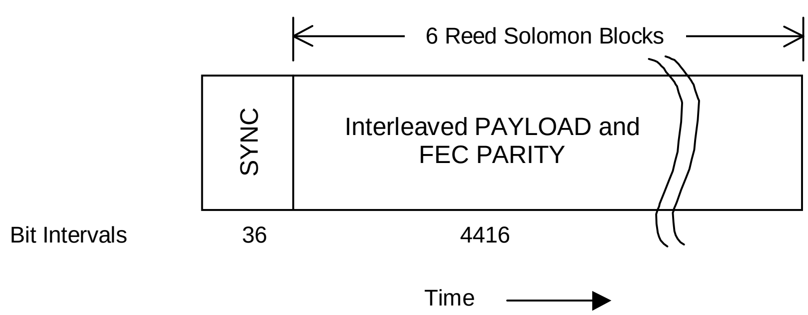


Figure 2.2.3.2: Ground Uplink Message Format

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 zeroes 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 in "big-endian" order; that is, the most significant byte, byte #1, is transmitted first, and within each byte, the most significant bit, bit #1, is transmitted first.

Table 2.2.3.2.2: 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	App Data Valid	Spare	(MSB)		Slot ID		(LSB)
8	(MSB)	TIS-B Site ID		(LSB)		Spare		
9								
				Application Data				
432								

2.2.3.2.2.1 UAT-Specific Header

2.2.3.2.2.1.1 Ground Station Latitude

The "GROUND STATION LATITUDE" field is a 23 bit (bit 1, byte 1 through bit 7, byte 3) field used to identify the ground stations latitude. The encoding of this field by the ground station will be the same as defined for latitude information in the ADS-B message (see Section 2.2.4.1.4).

2.2.3.2.2.1.2 Ground Station Longitude

The "GROUND STATION LONGITUDE" field is a 24 bit (bit 8, byte 3 through bit 7, byte 6) field used to identify the ground station's longitude. The encoding of this field by the ground station will be the same as defined for longitude information in the ADS-B message (see Section 2.2.4.1.4).

2.2.3.2.2.1.3 Position Valid

The "POSITION VALID" field is a 1 bit (bit 8, byte 6) field is used to indicate whether or not the position in the header is valid. ONE equals VALID, ZERO equals INVALID.

2.2.3.2.2.1.4 UTC Coupled

The "UTC-COUPLED" field is a 1 bit (bit 1, byte 7) field is used to indicate whether or not the ground station 1 Pulse per second timing is valid. ONE equals VALID, ZERO equals INVALID.

2.2.3.2.2.1.5 Application Data Valid

The "APPLICATION DATA VALID" field is a 1 bit (bit 2, byte 7) field is used to indicate whether or not the Application Data is valid for operational use. ONE equals VALID, ZERO equals INVALID.

Notes:

1. *Airborne applications should ignore all uplink reports when this bit is set to INVALID*

2. *This field will allow testing and demonstration of new products without impact to operational airborne systems*

2.2.3.2.2.1.6 Slot ID

The "SLOT ID" field is a 5 bit (bit 4, byte 7 through bit 8, byte 7) field is used 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 need to have no 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.*

2.2.3.2.2.1.7 TIS-B Site ID

The "TIS-B SITE ID" field is a 4 bit (bit 1, byte 8 through bit 4, byte 8) field conveys the reusable TIS-B Site ID that is also encoded with each TIS-B message as shown in Table 2.2.3.2.2.1.7 below

Table 2.2.3.2.2.1.7: Encoding of TIS-B Site ID

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

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

2.2.3.2.2.2 Ground Uplink Application Data

Definition of the Application Data field is beyond the scope of this MOPS 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:

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

Where P = 139

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

Note*: References for Forward Error Coding and the Galois Field are listed below:*

a. *Peterson, W. W., and E. J. Weldon, Jr.,* Error-Correcting Codes, *2nd ed., MIT Press, Cambridge, MA, 1972.*

b. *Michelson, A. M., and A. H. Levesque,* Error-Control Techniques for Digital Communication, *John Wiley & Sons, New York, NY, 1985.*

2.2.3.2.3.2 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 X 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 (RS) 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 the

Table, 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 Section 2.2.3.2)						FEC Parity (Block /Byte #)			
	1	2	3	…	71	72	A/1	…	A/19	A/20
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

Due to the weighty nature of this section, it is being provided separately.

2.2.5 Procedures for Processing of Time Data

UAT equipment will derive its timing from either internal or external UTC coupled time sources under normal—or "UTC Coupled"—conditions. UAT equipment will enter the the "non-UTC coupled" condition during any outage of the UTC coupled time source.

2.2.5.1 UTC Coupled Condition –External UTC Coupled Time Source

a. The UAT **shall** process a GPS/GNSS Time Mark pulse or an equivalent time synchronization indication.

b. The leading edge of the GPS/GNSS Time Mark pulse, or equivalent, **shall** be interpreted as indicating, within +/- 5 milliseconds, the time of applicability of Position, Velocity, and Time (PVT) information that is next to be received from the navigation source.

c. The "UTC Coupled" subfield **shall** be set to ONE.

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

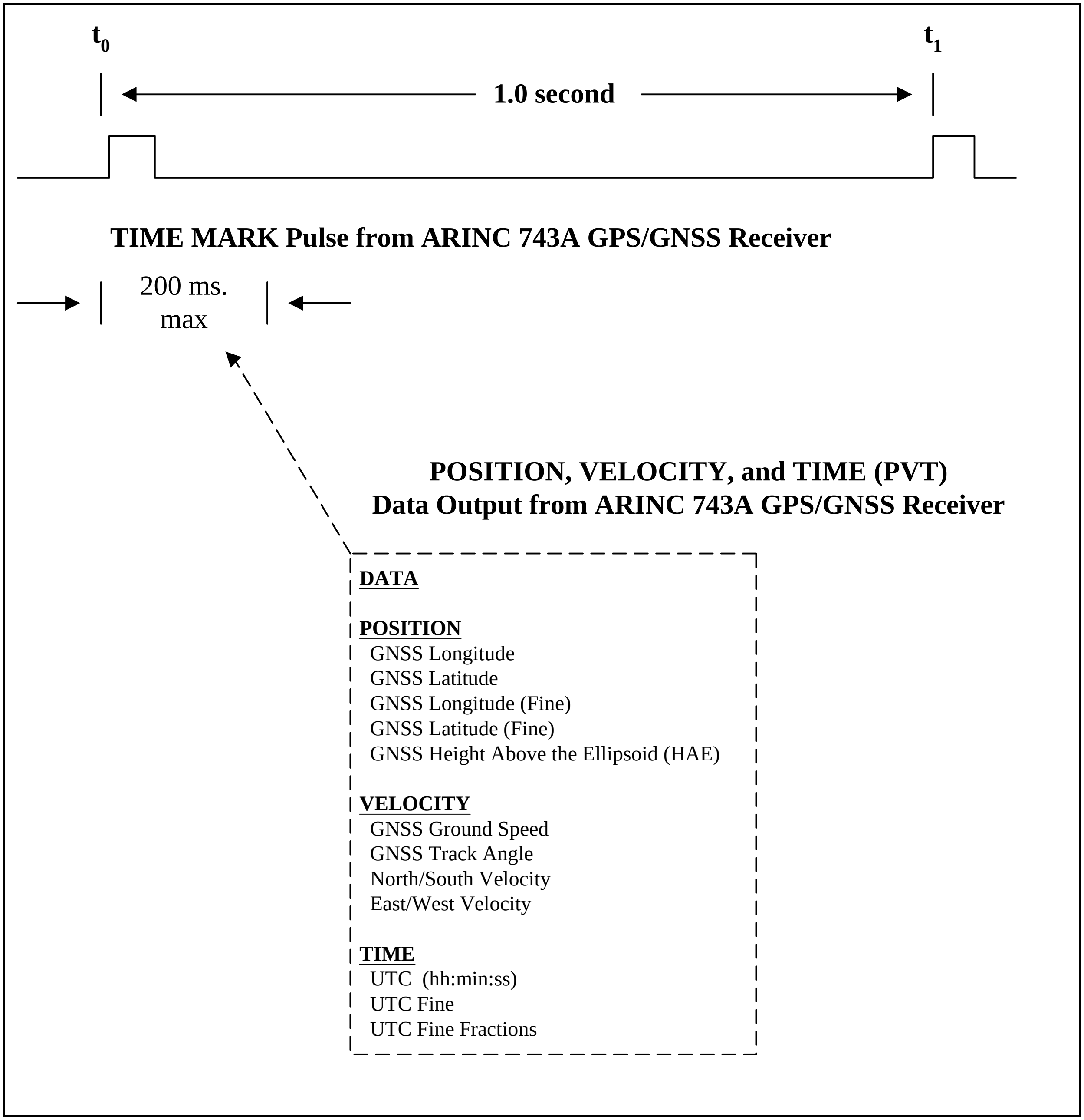


Figure 2.2.5.1: GPS/GNSS Time Mark Pulse

2.2.5.2 Non-UTC Coupled Condition

a. This condition **shall** be entered only upon the outage of the internal or external timing source for the UAT equipment. This is not the normal condition; it is a degraded mode of operation.

b. While in 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.

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 indefinitely.

f. The UAT equipment shall change state to the UTC coupled condition within 1 second of availability of the UTC coupled source.

Notes:

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. This should be achievable with an overall clock stability of less that this, since 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 requirement c) above.*

4. *This reversionary timing exists for the following reasons: a) support ADS-B message transmission using an alternate source of position and velocity, if available; b) support ADS-B message transmission in absence of position and velocity data in order that any available fields are conveyed (e.g., baro 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 Message Transmission Opportunity

Scheduling of the various ADS-B message types **shall** occur based on one of four possible Message Transmission Opportunities (MTO) available to each A/V (ADS-B transmitter). These are denoted as MTO-1, MTO-2, MTO-3, and MTO-4.

2.2.6.1.2 Message Transmission Cycle

A Message Transmission Cycle **shall** consist of exactly 16 seconds during which each MTO is scheduled four times as follows: MTO-2, MTO-1, MTO-3, MTO-4, MTO-4, MTO-2, MTO-1, MTO-3, MTO-3, MTO-4, MTO-2, MTO-1, MTO-1, MTO-3, MTO-4, MTO-2…

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

2.2.6.1.3 ADS-B Message Assignment to MTOs

The message scheduling mechanism **shall** provide the assignment of ADS-B message types to MTOs as shown in the Table 2.2.6.1.3.

<u>Table 2.2.6.1.3</u>: ADS-B Message Type Assignment to MTO

<table>
<tr><td colspan="2">Equipment Class</td><td>MTO-1</td><td>MTO-2</td><td>MTO-3</td><td>MTO-4</td></tr>
<tr><td rowspan="2">A0/A1/B1</td><td>Minimum Required</td><td rowspan="6">Long Type 1 OR Long Type 2 determined “On Condition”</td><td rowspan="2">Basic</td><td>Basic</td><td rowspan="2">Basic</td></tr>
<tr><td>Allowed</td><td>Long Type 5-11 Determined “On Condition”</td></tr>
<tr><td rowspan="2">A2</td><td>Minimum Required</td><td rowspan="2">Long Type 3</td><td rowspan="2">Long Type 3</td><td>Basic</td></tr>
<tr><td>Allowed</td><td>Long Type 5-11 Determined “On Condition”</td></tr>
<tr><td rowspan="2">A3</td><td>Minimum Required</td><td rowspan="2">Basic or Long Type 3-15 Determined “On Condition”</td><td rowspan="2">Long Type 3-15 Determined “On Condition”</td><td rowspan="2">Long Type 3-15 Determined “On Condition”</td></tr>
<tr><td>Maximum</td></tr>
<tr><td colspan="2">B2</td><td>Basic</td><td>Basic</td><td>Basic</td><td>Basic</td></tr>
</table>

2.2.6.1.4 Transmitter Antenna Diversity

For installations that support ADS-B message transmission from dual (diversity) antennas (see section 2.1), the installation **shall** be configured to transmit through Top (T) and Bottom (B) antennas each Message Transmission Cycle as shown in Figure 2.2.6.1.4.

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

|← Message Transmission Cycle →|

Time →

<u>Figure 2.2.6.1.4</u>: Transmitter Antenna Use for Diversity Installations

<u>Note:</u> *Antenna diversity could be implemented with dual redundant transmitters each connected to its dedicated antenna or from a single transmitter with antenna switching.*

2.2.6.1.5 Unavailability of Basic SV Message Payload Fields

a. In any UAT frame interval, each A/V **shall** at a minimum transmit the Basic ADS-B message regardless of the unavailability of any individual payload field.

b. Any such unavailable payload fields **shall** be encoded as “unavailable”.

2.2.6.2 ADS-B Message Transmit Timing

2.2.6.2.1 The Message Start Opportunity (MSO)

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

N(1) = 12 L.S.B.'s of the most recent valid latitude
N(2) = 12 L.S.B.'s of the most recent valid longitude

where the latitude and longitude are as defined in Section 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*.

For Class A0, A1, A2, and A3 equipment, the desired output of the algorithm is a 12-bit pseudorandom number in the range of 0 to 3199. Suppose the previous number is R(*m*-1) and

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

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

Notes:

1. *Retention of N(1) and N(2) in non-volatile memory is required to prevent common MSO selections amongst A/Vs when no valid lat/lon 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 symbol/bit of the UAT synchronization sequence at the antenna terminal of the UAT equipment **shall** occur at the beginning of the UTC second (as indicated by the GPS/GNSS Time Mark pulse or an equivalent) plus 250 microseconds times the MSO value determined from Section 2.2.6.2.1 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. See Appendix I for a discussion of UAT Timing Considerations. This sets the ultimate timing accuracy of the transmitted messages under the UTC Coupled condition.*

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 Generation 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 “ownship”.

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

Notes:

1. *Time of Applicability may be inferred by the receiving application in some installations*
2. *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*

2.2.7 UAT Transmitter Message Data Characteristic

2.2.7.1 UAT Transmitter Data Input Requirements

This section contains requirements for access to the inputs required to compose the ADS-B messages so their bits can be verified for their mapping into the structure of the transmitted message. The requirements of this section are strictly to support test and as such do not contain a corresponding dedicated test procedure in Section 2.4

[Do we need class dependent requirements here?]

[how to account for fact that not all installations will require every input, e.g., some G/A may not need 24 bit perm address?]

2.2.7.1.1 Ownship Address Information

a. The ADS-B transmitting device **shall** accept own vehicle Address Type information via an appropriate data input interface to establish the Address Qualifier field of ALL ADS-B Messages as identified in Figure 2.2.4.1-A

b. The ADS-B transmitting device **shall** accept own vehicle Address Type information and the permanent 24-bit Discrete Address (subparagraph X), via an appropriate data input interface. The ADS-B transmitting device **shall** format such data into the Address field (byte 2, bit 1 through byte 4, bit 8) of ALL ADS-B Messages as identified in Figure 2.2.4.1-A.

Notes:

1. *The Address Type input is used to indicate to the transmitter whether the permanent or temporary 24 bit address is to be used.*
2. *Verification of the temporary address will also require an input for ownship latitude and longitude*

2.2.7.1.2 Own Position Latitude Data

The ADS-B transmitting device **shall** accept own position Latitude information via an appropriate variable data input interface and use such data to establish the "Latitude" field (byte 5, bit 1 through byte 7, bit 7) of the Basic ADS-B message payload as identified in Figure 2.2.4.1-A.

2.2.7.1.3 Own Position Longitude Data

The ADS-B transmitting device **shall** accept own position Longitude information via an appropriate variable data input interface and use such data to establish the "Longitude" field (byte 7, bit 8 through byte 10, bit 7) of the Basic ADS-B message payload as identified in Figure 2.2.4.1-A.

2.2.7.1.4 Integrity and Accuracy Parameters

[will deal with NIC, NACp, NACv, and SIL fields]

2.2.7.1.5 Air/ground Status and Horizontal Velocity Data

2.2.7.1.5.1 Input Data

The ADS-B transmitting device **shall** accept the following information via an appropriate variable data input interface:

a. an ON GROUND/AIRBORNE indication

b. North Velocity

c. East Velocity

d. Ground Speed

e. Heading

2.2.7.1.5.2 Output Message Fields

The ADS-B transmitting device **shall** use the input data to establish the fields of the Basic ADS-B message payload listed below:

a. "Air/Ground State" (byte 12, bits 3 and 4) as identified in Figure 2.2.4.1-A.

b. "V Valid" (Byte 12, bit 5) as identified in Figure 2.2.4.1-A.

c. "North Velocity or Ground Speed" (byte 12, bit 6 through byte 13, bit 8) as identified in Figure 2.2.4.1-A.

d. "East Velocity or Heading" (byte 12, bit 6 through byte 13, bit 8) as identified in Figure 2.2.4.1-A.

2.2.7.1.6 Altitude Data

2.2.7.1.6.1 Input Data

The ADS-B transmitting device **shall** accept the following information via an appropriate variable data input interface:

a. Pressure Altitude

b. GNSS Height Above Ellipsoid (HAE)

c. Control Input for assigning Pressure Altitude or GNSS HAE to Primary or Secondary Altitude respectively.

2.2.7.1.6.2 Output Message Fields

The ADS-B transmitting device **shall** use the input data to establish the fields listed below:

a. "Alt Type" (byte 15, bit 4) of the Basic ADS-B message payload as identified in Figure 2.2.4.1-A

b. "Primary Altitude" (byte 15, bit 5 through byte 16, bit 8) of the Basic ADS-B message payload as identified in Figure 2.2.4.1-A.

c. "Secondary Altitude" (byte 30, bit 7 through byte 32, bit 2) of the Long Type 1 ADS-B message payload as identified in Figure 2.2.4.2-A.

2.2.7.1.7 Vertical Rate Data

[To be provided]

2.2.7.1.8 Time Data

This requirement is covered in Section 2.2.5

2.2.7.1.9 Participant Category Code and Aircraft Identification (*or* Registration) Data

2.2.7.1.9.1 Input Data

The ADS-B transmitting device **shall** accept the following information via an appropriate variable data input interface:

a. Own vehicle Participant Category Code

b. Own vehicle Aircraft Identification Data

c. When Aircraft Identification or Flight Number data specified in subparagraph b is not available or is not valid, the ADS-B transmission device **shall** accept own vehicle Aircraft Registration Character Data (N250DL, etc.).

d. Only if Aircraft Identification or Flight Number Data, and Aircraft Registration Data is not available to the ADS-B transmission device, **shall** the device enter ALL ZEROs into the character fields specified in subparagraph 2.2.3.2.5.3.

2.2.7.1.9.2 Output Message Field

The ADS-B transmitting device **shall** use the input data to establish the "Participant Category Code and Flight ID (Call Sign)"fields of the Long Type 1 ADS-B message payload.

2.2.7.1.10 Version Number Data

The ADS-B transmitting device **shall** accept the Version Number via an appropriate variable data input interface and use such data to establish the "Version Number (VN)" subfield in the Long Type 1 ADS-B Message (see subparagraph X) as specified in subparagraph X.

If appropriate Version Number data is not available to the ADS-B transmission device, then the device **shall** set the "Version Number" subfield specified in subparagraph X to ZERO.

2.2.7.2 Time Registration and Latency

This subsection 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.

2.2.7.2.1 Requirements when NUC <= 7 and UTC Coupled

a. At the time of 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. At the time of ADS-B message transmission, any updated ADS-B message fields provided to the transmitter up to 200 milliseconds into the current 1 second UTC Epoch (the cutoff time) **shall**—with 95% confidence—be reflected in the subsequent transmitted message containing that message field.

Notes:

1. See Figure 2.2.7.2.1

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

3. *Velocity information cannot be extrapolated and may therefore have additional ADS-B imposed latency than that reflected in Figure 2.2.7.2.1*

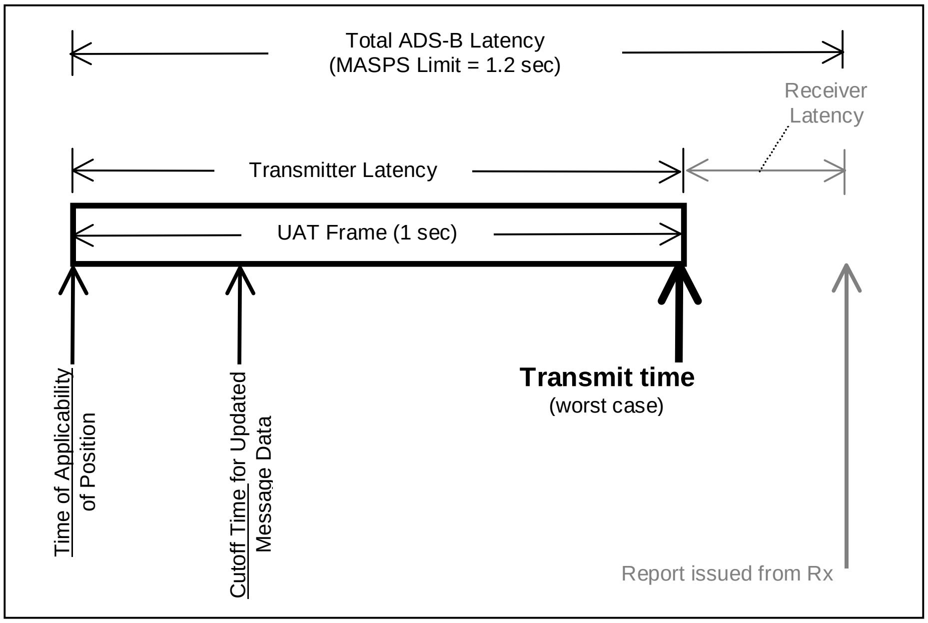


Figure 2.2.7.2.1 UAT Transmitter Data Timing—NUC <= 7

2.2.7.2.2 Requirements When NUC >= 8 and UTC Coupled

a. At the time of ADS-B message transmission, 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. At the time of ADS-B message transmission, any updated ADS-B message fields provided to the transmitter by the start of the current 0.2 second UTC Epoch at (the cutoff time) **shall**—with 95% confidence—be reflected in the subsequent transmitted message containing that message field.

Notes:

1. *See Figure 2.2.7.2.2*

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

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

4. *Velocity information cannot be extrapolated and may therefore have 200 milliseconds additional ADS-B imposed latency than that reflected in Figure 2.2.7.2.2*

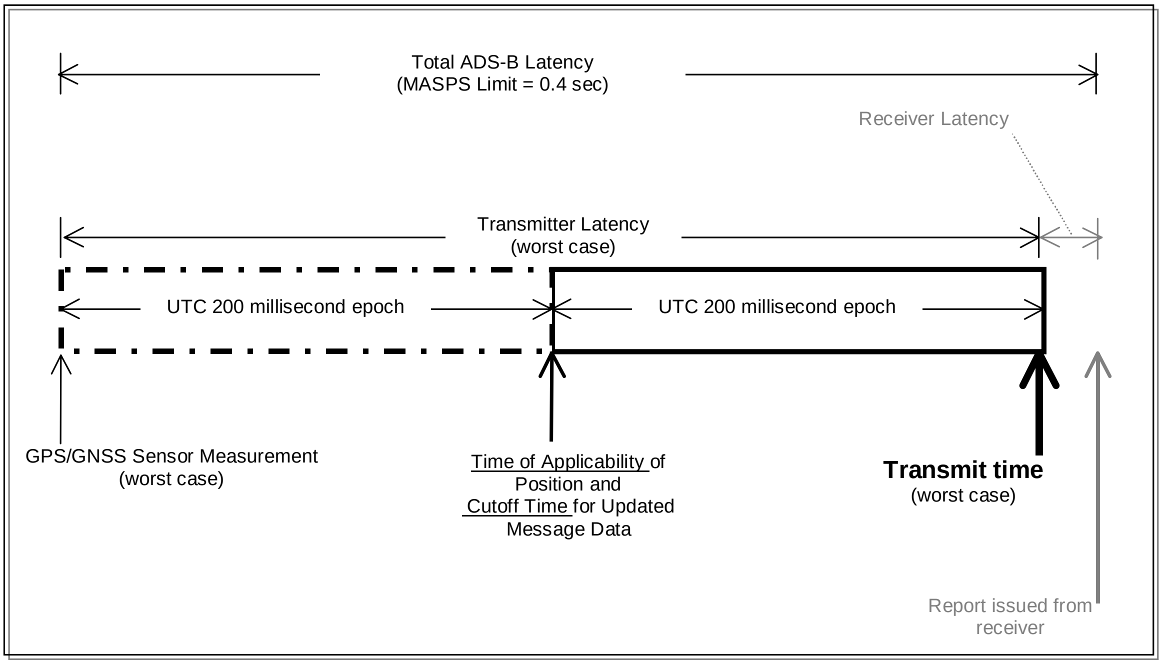


Figure 2.2.7.2.2 UAT Transmitter Data Timing—NUC >= 8

2.2.7.2.3 Requirements when Non-UTC Coupled

a. At the time of ADS-B message transmission, any updated ADS-B message fields provided to the transmitter up to 800 milliseconds prior to the transmit time (the cutoff time) **shall**—with 95% confidence—be reflected in the subsequent transmitted message containing that message field.

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

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 either channel are provided to the report generation function. In the event both channels result in Successful Message Reception of identical messages, a single copy of this message may be provided to the report generation function.

b. 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 to 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.

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

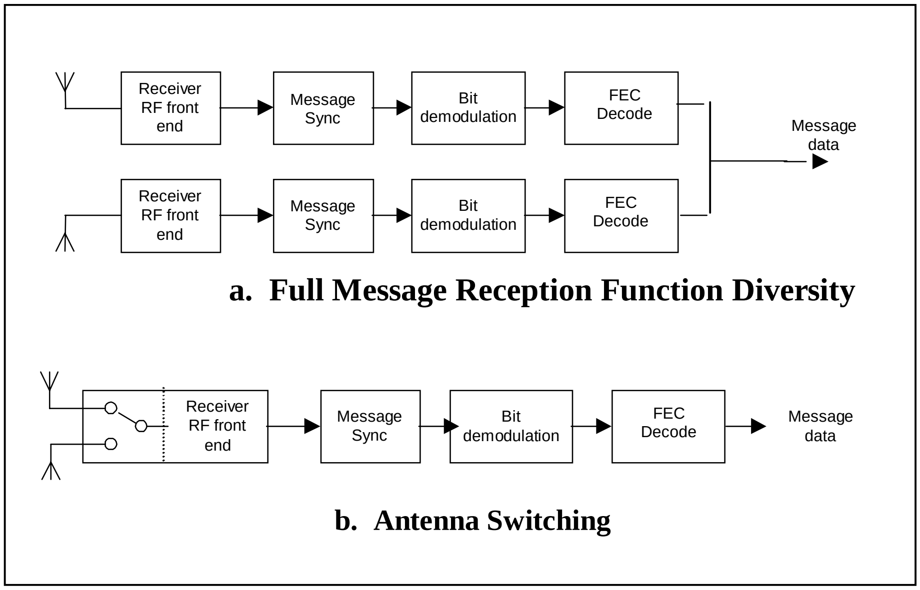


Figure 2.2.8.1: ADS-B Receiving Architectures.

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 maximum 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 air-to-air Doppler at 1200 knots closure/opening.

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

2.2.8.2.1.2 Ground Uplink Message is Desired Signal

A maximum desired signal level of –90 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 Section 2.2.2.4.

Notes:

1. *The ground station transmitter will maintain the same level of modulation distortion even though the Ground Uplink message is significantly longer in duration.*

2. *This test ensures the baud rate stability supporting demodulation in the unit under test is adequate (~20 ppm) to properly receive the longer Ground Uplink message.*

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.

Note:

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 ownship transmission to meet the requirements of Section 2.2.9.3 may need to achieve Successful Message Reception at significantly higher levels than –10 dBm*

2.2.8.2.3 Receiver Selectivity

The receiver **shall** provide the following maximum 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	**Maximum Rejection Ratio (Desired/Undesired level in dB)**	
	Equipment Class A0, A1 and A2	Equipment Class A3
1.0 MHz	[-15]	[??]
2.0 MHz	[-50]	[??]
10.0 MHz	[-60]	[??]

Notes:

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

2. *This establishes the receiver's rejection of off channel energy radiated from DME ground stations adjacent to the UAT guard band.*

2.2.8.2.4 Receiver Tolerance to Pulsed Interference

[Tom Pagano will give this some thought]

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 signals, **shall** result when the level of the stronger signal is at –80 dBm and the stronger signal is at least ***X*** dB above the weaker signal under each of the following conditions:

a. With the stronger signal and weaker signal aligned in time

b. With the weaker signal preceding the stronger signal

c. With the stronger signal preceding the weaker signal

Where the value of X is listed below

[6 dB] for Equipment Class A0, A1, and A2

[10 dB] for Equipment Class A3

Notes:

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

2. *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. Full diversity reception required A3 class allows it to maintain adequate air-air surveillance performance for A0 ,A1 and A2 targets.*

3. *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 as a result of R/S decoding.

[Tests for this requirement should include tests with correctable and uncorrectable errors using short and long ADS-B]

Notes:

1. *Message format (Basic vs Long ADS-B) can be ascertained by attempting to decode both forms of the R/S block if necessary.*

[Add note on the excellent UMER achieved through the R/S code used—Warren?]

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 R/S block of the Ground Uplink message **shall** be individually examined for errors. Each R/S block **shall** be declared as valid only if it contains NO uncorrected error after R/S decoding.

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

Test for this requirement should include tests with correctable and uncorrectable Ground Uplink messages formatted, coded and interleaved per Section 2.2.3.2]

[Add note on the excellent UMER achieved through the R/S code used—Warren?]

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

The receiver **shall** NOT infer message type for decoding based on its location within the UAT frame as shown in [Figure 1.x].

Note: *The polarity of the correlation score from the synchronization process is available for distinguishing these message types.*

2.2.8.3.3 Synchronization Pattern Contained in Message Payload

Successful Message Reception **shall** occur under each of the following conditions:

a. the ADS-B synchronization pattern is contained in the payload of an ADS-B message

b. the Ground Uplink synchronization pattern is contained in the payload of an ADS-B message

c. the ADS-B synchronization pattern is contained in the interleaved payload of a Ground Uplink message

d. the Ground Uplink synchronization pattern is contained in the interleaved payload of a Ground Uplink message

Note: *These requirements ensure that a receiver capable of the "retrigger" procedure does not abandon the "original trigger" when the original message is decodable.*

2.2.8.3.4 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 one second

b. Resolution of 100 nanoseconds or less

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

d. Accuracy of +/- 500 nanoseconds of the actual time of receipt for UAT equipment using an external UTC coupled time source.

Notes:

1. *The TOMR value need only be expressed in terms of offset from the 1 Pulse Per Second (PPS) UTC time mark just prior to reception.*

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

2.2.9 Report Generation Requirements

Reports **shall** be generated for on-board applications in direct response to each Successful Message Reception.

2.2.9.1 Report Generation on Receipt of ADS-B Message

Reports **shall** contain the following information

a. All elements of the received message payload 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 inferred by the receiving application in some installations

2.2.9.2 Report Generation 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 inferred by the receiving application in some installations

2.2.10 Receiver Subsystem Throughput Requirements

Receiver subsystem **shall** meet the conditions and requirements given in Table 2.2.10 below.

Table 2.2.10: Message-to-Report Throughput Requirements

Equipment Class of ADS-B Receiving Subsystem	Total Message Load (input messages per second)		Time from RF message input to Report output (Milliseconds-95%)	
	Ground Uplink	Long ADS-B	Ground Uplink	Long ADS-B
A0	[10]	[100]	[500]	[500]
A1	[16]	[200]	[500]	[500]
A2	[16]	[400]	[500]	[500]
A3	[16]	[400]	[500]	[500]

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 symbol of one transmit message and the optimum sampling point of the first symbol 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 symbol of one receive message and the optimum sampling point of the first symbol of the synchronization sequence of the subsequent transmit message.*

2.2.12 Response to Mutual Suppression Pulses

Mutual suppression systems may be needed if the aircraft has other pulse L-band (also known as D-band) equipment on board or if the ADS-B equipment is used in conjunction with certain Collision Avoidance System equipment.

2.2.12.1 ADS-B Transmitting Device Response to Mutual Suppression Pulses

If the ADS-B transmitting equipment is designed to accept and respond to mutual suppression pulses from other electronic equipment in the aircraft (to disable the equipment while the other equipment is transmitting), the equipment **shall** regain normal transmission capability not later than 15 microseconds after the end of the applied mutual suppression pulse.

[Why does a transmitter need to respond to mutual suppression at all?]

2.2.12.2 ADS-B Receiving Device Response to Mutual Suppression Pulses

If the ADS-B receiving equipment is designed to accept and respond to mutual suppression pulses from other electronic equipment in the aircraft (to disable the equipment while the other equipment is transmitting), the equipment **shall** regain normal sensitivity, within 3 dB, not later than 15 microseconds after the end of the applied mutual suppression pulse.

Note: *This document does not establish the design parameters of the mutual suppression system. However, it is recommended that all sources of mutual suppression pulses be dc coupled while sinks are ac coupled. This standardization will prevent source or sink failures from disabling all users of the mutual suppression pulses.*

2.2.13 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 at the rates defined in subparagraphs X. If any of the ADS-B message types for which the equipment is certified is not transmitted at the specified rates, 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

Non-transponder implemented ADS-B transmission devices **shall** declare a device failure in the event that it's own ICAO 24-bit Address is set to all "ZEROs" or all "ONEs."

2.2.13.4 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 singe Fail/Warn output that is used in common to satisfy the requirements of subparagraphs X. 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

ADS B systems require omni-directional antenna(s) for transmitting and receiving.
Separate antenna for receiving and transmitting are not required.

2.2.14.1 Transmit Pattern Gain

The gain of an omni-directional transmit antenna **shall** not be less than the gain of a matched quarter-wave stub minus 3 dB over 90 percent of a coverage volume from 0 to 360 degrees in azimuth and from 5 to 30 degrees above the ground plane when installed at center of 1.2 meter (4 feet) diameter (or larger) flat circular ground plane and measured to [978] MHz.

2.2.14.2 Receiver Pattern Gain

The gain of an omni-directional antenna should not be less than the gain of a matched quarter-wave stub minus one dB over 90% of a coverage volume from 0 to 360 degrees in azimuth and -15 to +20 degrees in elevation when installed at the center of a 1.2 m (4 ft.) diameter (or larger) circular ground plane that can be either flat or cylindrical and measured at [978] MHz.

Note: *These requirements are consistent with those provided in RTCA Document No. DO-185A, section 2.2.4.7.1.*

[Will verification of these requirements be too burdensome, especially for A0/A1 Class?]

2.2.14.3 Impedance and VSWR

The VSWR produced by each antenna when terminated in a 50 ohm transmission line **shall** not exceed 1.5:1 at [978] MHz.

Isnt this one redundant with the reqirement above? Of the two, isnt this one all we really need?

2.2.14.4 Polarization

Antenna(s) **shall** be vertically polarized.

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 Section 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 Section 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.