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6 November 2001

RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #8

DRAFT 6 of Section 2.2 of the UAT MOPS (excluding Section 2.2.4)

Presented by Chris Moody

SUMMARY
The following represents a fifth draft of Section 2.2. Subsection 2.2.4 is excluded here and will be subsequently presented as a separate document. The following new glossary items should be defined as a result of this update: UTC time: - UTC time as defined by the appropriate Civil Aviation authorities UTC 1 second epoch signal: - The reference timing used to establish message transmit and reception times with precision, as well the time of applicability of Position and Velocity when the UAT transmitter is “UTC Coupled” to a GPS/GNSS navigation source MSO: - Message Start Opportunity. Discrete times separated by 250 usec which define the moments when messages can be transmitted. The MSO selected for each transmission changes each second as a result of a pseudorandom process. MTO: - Message Transmission Opportunity. MTOs are used to determine the scheduling for transmission of the various ADS-B message types. There are four separate MTOs scheduled in a predefined sequence. A MTO occurs each second. Message Transmission Cycle: - A period of 16 seconds in which each MTO appears four times in a pattern that ensures a proper mix of message types are distributed to both Top and Bottom antennas when diversity transmission is used.

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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 Extended 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 modulation rate shall be 1.041667 megabaud, +/- 20 PPM.

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 and rate. However, the rate tolerance for these messages will be +/- 2 PPM to support proper demodulation over their longer duration.*

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 Δf/2 (+312.5 kHz) and a binary 0 by a shift of -Δf/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 msec). 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 Accuracy

[It may be most straightforward to define this in terms of the eye diagram. Since this is FM and phase modulation, we don’t really need a full I and Q measurement (i.e., Error Vector Magnitude). Perhaps we could say the opening of the eye should be no less than X kHz. The perfect value for X is 625 kHz so we need to determine a value somewhat less than that. We also need to define how to measure the eye (i.e., for how long, very high SNR, etc).] From Meeting #8 - Warren Wilson will provide the words for this section. Can this requirement also account for the 20 PPM offset? Can we relate the eye opening in Hz to the FSK error measurement in percent?

2.2.2.5 Transmitter Power Output

The UAT transmit function shall have 4 states, defined as follows:

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. Active state: The Active state begins at the beginning of the Ramp-Up period, and extends until the end of the Ramp-Down period. During the Active state, RF output power at the antenna terminals shall comply with Section 2.2.3.1.1. [We may need to specify “droop” to be about 1dB over the message in order to reflect the simulation.]

d. 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 2-1. **Tom Mosher to get back to WG for the January Meeting to resolve the previous bracketed items.**

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.

Table 2.2.2.6: UAT Transmit Spectrum

Frequency Offset From Center	Required Attenuation from Maximum (dB)
All frequencies in the range 0-0.5 MHz	0
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

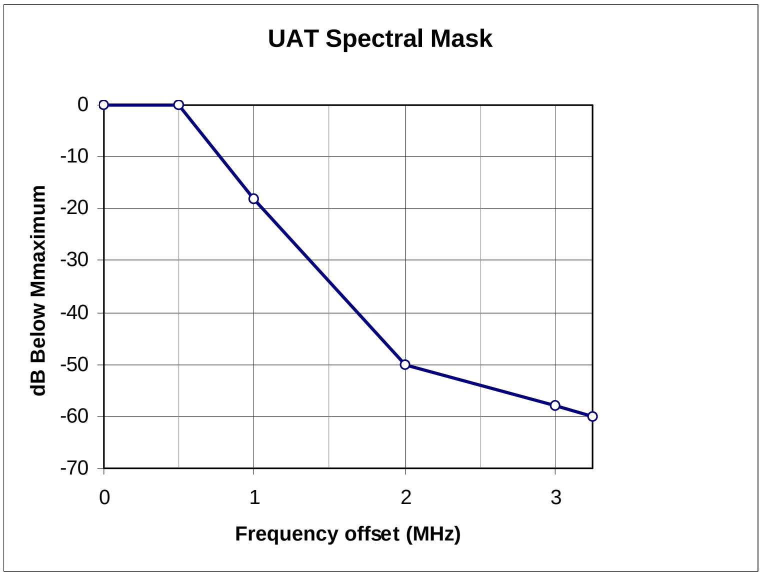

Figure 2.2.2.6: UAT Transmit Spectrum

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

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.

2.2.3 Broadcast Message Characteristics

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.

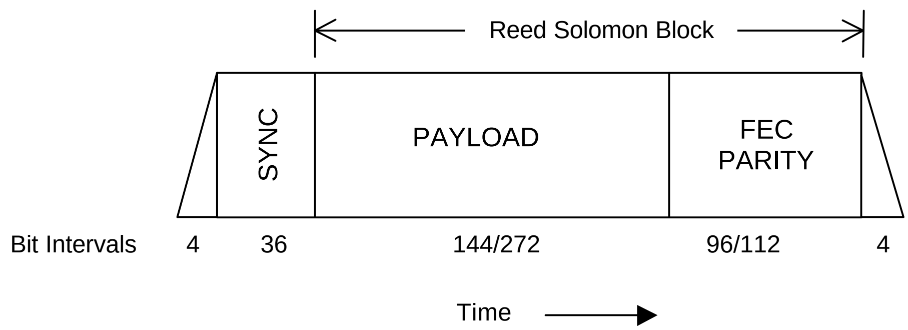

Figure 2.2.3.1: ADS-B Message Format

NOTE: Traffic Information Services-Broadcast (TIS-B) messages are identical to ADS-B messages in format. TIS-B messages are therefore not defined separately.

2.2.3.1.1 Ramp Up/Down

To minimize transient spectral components, the transmitter power shall ramp up and down at the start and end of each burst. The maximum time duration of these ramps shall be no more than 4 bit periods each. Ramp up time is defined as the time between the transmitter power level at the end of the Pre-Key state to 90% of full power output. Ramp down time is defined as the time to decay from full power to the level at the start of the Post-Key state. Full power shall be as specified by the ranges listed in Table 2-1 for the equipment class. During ramp up and down, the modulating data shall be all zeroes.

2.2.3.1.2 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.

2.2.3.1.3 Payload

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

2.2.3.1.4 FEC Parity

2.2.3.1.4.1 Code Type and Rate

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 rates:

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

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 rate

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:

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

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

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

Note*: 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*.

2.2.3.1.4.2 Generation and Transmission Order

[to be provided by John Barrows by Meeting 9]

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.

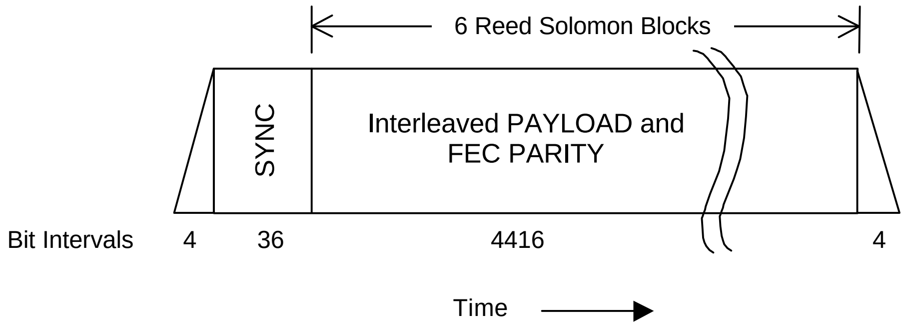

Figure 2.2.3.2: Ground Uplink Message Format

2.2.3.2.1 Ramp Up/Down

To minimize transient spectral components, the ground station transmitter power will ramp up and down at the start and end of each burst. The maximum time duration of these ramps will be no more than 4 bit periods each. Ramp up time is defined as the time between the transmitter power level in the Pre-Key state to 90% of full power output. Ramp down time is defined as the time to decay from full power to the Post-Key level. During ramp up and down, the modulating data shall be all zeroes.

2.2.3.2.2 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.*

2.2.3.2.3 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 2.2.3.2.3. Bytes will be transmitted with Bit #1 first. **We need a requirement in the UAT Receiver section, for the UAT Receiver to pass through bytes 1 to 432 to an output interface, assuming successful decode.**

<u>Table 2.2.3.2.3</u>: Format of the Ground Uplink Message Payload.

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

2.2.3.2.3.1 UAT-Specific Header

2.2.3.2.3.1.1 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).

2.2.3.2.3.1.2 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).

2.2.3.2.3.1.3 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.

2.2.3.2.3.1.4 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.

2.2.3.2.3.1.5 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.

<u>Note:</u> *This field will allow testing and demonstration of new products without impact to operational airborne systems*

2.2.3.2.3.1.6 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.*

2.2.3.2.3.1.7 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 2.2.2.6 below

Table 2.2.2.6: 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.*

2.2.3.2.3.2 Ground Uplink Application Data

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

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

2.2.3.2.4.1 Code Type and Rate

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 rate.

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

The primitive polynomial of the code is as follows:

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

The generator polynomial is as follows:

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

Where P = 139

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

Note: *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.*

2.2.3.2.4.2 Output Order

[to be provided by John Barrows by Meeting 9]

2.2.3.2.5 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 2.2.3.2.5. 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 2.2.3.2.5: Ground Uplink Interleaver Matrix

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

Note: *In Figure 2.2.3.2.5, 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*

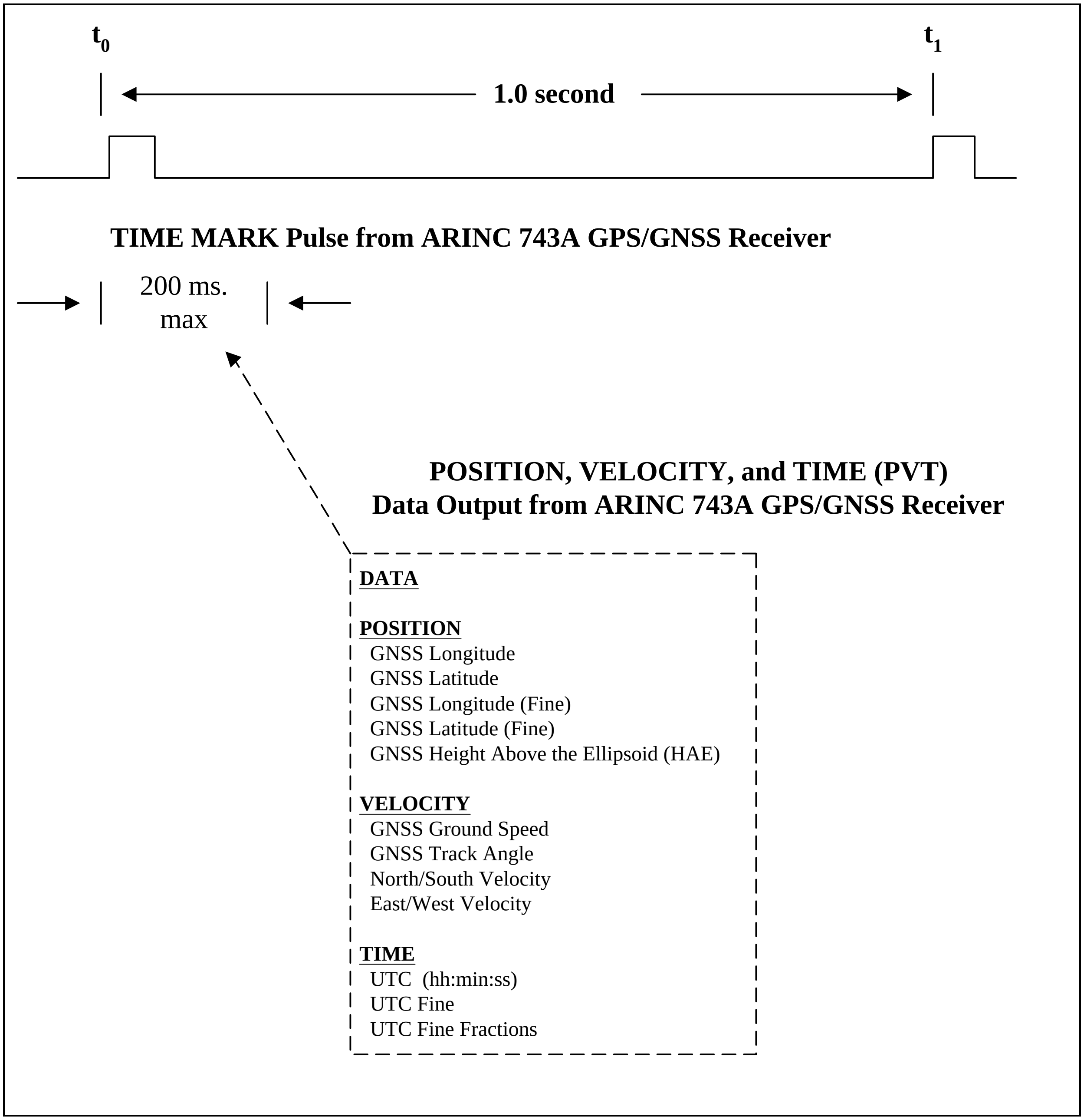

Figure 2.2.5.1: GPS/GNSS Time Mark Pulse

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 +/- 2 milliseconds of UTC time based upon successful message reception of any Ground Uplink Message.

d. While in the non-UTC Coupled Condition, but lacking availability of Ground Uplink Messages, 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 10 minutes.

Notes:

1. *The 10 minute requirement above is consistent with the modulation rate accuracy and the 12 millisecond air-ground segment guard time.*

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. *An alternative procedure to maintaining time upon failure of the primary source is to derive time from receipt of Ground Uplink Messages by the receiving subsystem per Section 2.2.9.3. When using this procedure the estimated 1 second UTC epoch signal does NOT indicate the time of validity of PVT.*

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 twice 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.

Table 2.2.6.1.3: ADS-B Message Type Assignment to MTO

<table>
<tr><th colspan="2">Equipment Class</th><th>MTO-1</th><th>MTO-2</th><th>MTO-3</th><th>MTO-4</th></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">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

Figure 2.2.6.1.4: Transmitter Antenna Use for Diversity Installations

Note: *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.

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

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

N(1) = 12 L.S.B.'s of the current latitude (per encoding of Section **X**)
N(2) = 12 L.S.B.'s of the current longitude (per encoding of Section **X**)

where the latitude and longitude are as defined in Section 2.2.4.1.2 and 2.2.4.1.3 respectively. The next random number is then given by:

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

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

Note: *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.*

2.2.6.3 Time of Applicability of ADS-B Message Payload Fields

2.2.6.3.1 Position and Velocity (UTC Coupled)

At the time of ADS-B message transmission, position and velocity information encoded in the Latitude, Longitude, N-S Velocity, and E-W Velocity fields shall be applicable as of the start of the current UTC second.

Note: *Specifically, any extrapolation performed shall be to the start of UTC second and not the time of transmission.*

2.2.6.3.2 Position and Velocity (Non-UTC Coupled)

[To be provided]

2.2.6.3.3 Latency of Other Message Payload Fields (UTC or Non-UTC Coupled)

Any change in information affecting the ADS-B message payload fields shall be reflected in the encoding of that field, provided that the change occurs and is available to the ADS-B transmitting subsystem within at least ***X*** milliseconds prior to the next scheduled ADS-B message transmission containing that field. Table 2.2.6.3.3 below shows the value of ***X*** for each field.

Table 2.2.6.3.3: Latency of ADS-B Message Fields

ADS-B Message Payload Field	Value of X (in milliseconds)
25-Bit UAT Address	1000
Latitude	Section 2.2.5.4.2 and 2.2.5.4.3 applies
Longitude	Section 2.2.5.4.2 and 2.2.5.4.3 applies
NUCp (NIC/NAC)	100
Turn Indicator	100
Horizontal Pos Available	100
UTC Coupled	100
N-S Velocity	Section 2.2.5.4.2 and 2.2.5.4.3 applies
E-W Velocity	Section 2.2.5.4.2 and 2.2.5.4.3 applies
Pressure Altitude	100
Pressure Altitude Rate	100
A/G State	100
Geodetic Height Difference	100
Height Valid	100
Emergency/Priority Status	100
Geodetic Height Difference Rate	100
Aircraft Category subfield	Not changeable
Flight ID subfield	1000
Message Start Opportunity	Must use value established by ADS-B transmitting subsystem for the current frame

2.2.7 Receiver Characteristics

2.2.7.1 Receiver Sensitivity

A maximum desired signal level of –93 dBm applied at the antenna end of the feedline shall produce a rate of Successful Message Reception of 90% or better, for Long ADS-B message types under the following simultaneous conditions:

a. The receiver shall be capable of Successful Message Reception with the maximum permitted signal frequency offset plus air-to-air Doppler at 1200 knots closure/opening.

b. A Successful Message Reception rate of 90% or better shall be achieved when the desired ADS-B message signal is subject to a symbol rate offset of +/- 20 ppm.

2.2.7.2 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.

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

2.2.7.3 Receiver Reception of Overlapping ADS-B Messages

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 [6 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

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

2.2.7.4 Receiver Synchronization Pattern Occurring Within the ADS-B Message Payload

The receiver shall successfully decode an ADS-B message containing the 36-bit synchronization pattern that occurs in the message payload.

2.2.7.5 Receiver Receipt of Ground Uplink Messages

The receiver shall decode and de-interleave Ground Uplink Messages defined as per

2.2.7.6 Receiver Selectivity

The receiver shall provide the following maximum signal rejection ratios as a function of frequency offset as listed in Table 2.2.7.6.

Table 2.2.7.6: Selectivity Rejection Ratios

Frequency Offset from Center	Maximum Rejection Ratio (Desired/Undesired level in dB)	
	Equipment Class A0 and A1	Equipment Class A2 and 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.*

2.2.7.7 Receiver Tolerance to Pulsed Interference

[Test to verify FEC operation and receiver recovery time from high level on-channel interfering pulse at around –40 dBm when detecting signal near sensitivity. Test should allow for random pulse placement across the message]

2.2.7.8 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. +/- 500 nanoseconds of the actual time of receipt for UAT equipment using an internal UTC coupled time source.

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

2.2.7.9 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.

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

2.2.7.10 Receiver Antenna Switching

Installations that switch a single receiver alternately between top and bottom antennas shall make a switch each second using the following pattern:

Top, Bottom, Top, Bottom …

2.2.8 ADS-B Transmitter Data Characteristics

2.2.8.1 ADS-B 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—to be provided. The requirements of this section are strictly to support test]

2.2.8.2 ADS-B Transmitter Message Latency

[this section contains requirements for how quickly changes in various message elements get propagated onto the RF message after they are available to the transmitter input—to be provided]

2.2.9 Report Generation Requirements

Reports shall be generated for on-board applications in direct response to each received message. Exactly one report shall be generated for each message successfully received. **Need a requirement to provide, as an output report any ADS-B Message transmitted by own ship. It must be identified as such!**

2.2.9.1 Report Generation on Receipt of ADS-B Message

2.2.9.1.1 Message Integrity Requirements

A received ADS-B message shall result in an output report only if the message reception process indicates there are NO uncorrected errors as a result of R/S decoding.

2.2.9.1.2 Report Contents

Reports shall contain the following information

a. All elements of the message payload

b. An explicit message time of applicability

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

2.2.9.2 Report Generation on Receipt of Ground Uplink Message

2.2.9.2.1 Message Integrity Requirements

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. A received Ground Uplink Message shall result in an output report only if all six constituent R/S blocks are declared valid from a) above.

2.2.9.2.2 Report Contents

Reports shall contain the following information:

a. All elements of the message payload

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

2.2.10 Receiver Subsystem Throughput Requirements

2.2.10.1 Input Message Capacity

[What total ADS-B and Gnd Uplink load is reasonable in full NAS environment?]

2.2.10.2 Output Report Latency

[Need reasonable number for latency from message arrival at rx antenna to issuance of report under the load established for 2.2.8.1. Appendix K of DO-242 allows up to 100 ms for "report assembly"]

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 Self Test and Monitors

2.2.13 Interfaces