UAT-WP-2-04
20 February 2001

RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #2

DRAFT 1 of Section 2.2 of the UAT MOPS

(Presented by Chris Moody)

SUMMARY
The following represents our first draft of Section 2.2 in what should be the official template. It is basically the Section 2.2 from the previous UAT preliminary document, with a few tweaks. We put into yellow highlighting the areas that need attention for sure.

RTCA, Inc.
1140 Connecticut Avenue, NW, Suite 1020
Washington, DC 20036-4001, USA

UAT Draft MOPS Section 2.2
12 Feb 2001

Updated: Month day, year
RTCA/DO-???

Prepared by: RTCA, Inc.

TABLE OF CONTENTS

1 PURPOSE AND SCOPE

2 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.2 Equipment Performance – Standard Conditions

2.2.1 Definition of Standard Conditions

2.2.1.1 Signal Levels

Unless otherwise noted, the signal levels specified for transmitting devices in this subsection exist at the antenna end of 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 [X] MHz +/- [20] PPM.

2.2.2.2 Modulation Rate

The modulation rate shall be 1.041667 megabaud/second +/- [100] PPM. Each baud represents one bit. [However, receiver will have to have around a 20 PPM baud clock to demodulate the longer uplinks, so should we just make it 20 PPM?]

NOTE: Ground Uplink Messages will use the same modulation type and rate. However, the rate tolerance for these messages will be +/- 10 PPM to support proper demodulation over their longer duration.

NOTE: Each baud represents one bit thus making each bit period 0.96 microsecond

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.

NOTE: Filtration of the transmitted signal will be required to meet the spectral containment requirement of Section 2.2.2.5. This filtration will cause overshoot in the deviation, making the maximum deviation close to +/-450 kHz at points outside the optimum sampling point.

2.2.2.4 Transmitter Power Output

2.2.2.4.1 Minimum Power During the Active State

The minimum RF peak output power for each UAT equipment class shall be as given in Table 2-1.

2.2.2.4.2 Maximum Power During the Active State

The maximum RF peak output power of each transmitted message at the terminals of the antenna shall be fixed at 160W for all classes of equipment.

2.2.2.4.3 Maximum Power During the Inactive State

When the transmitter is in the inactive state, the RF output power at the antenna terminals shall not exceed –80 dBm when measured at f_0 in a 1 MHz bandwidth.

NOTE: The inactive state is defined to include all time other than the time required for ADS-B message transmission. ADS-B message transmission is inclusive of the time allowed for ramp up and ramp down intervals as defined in Section 2.2.3.1.

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 antenna exceeds 20 dB.

2.2.2.5 Transmission Spectrum

[A spectrum mask specification is needed]

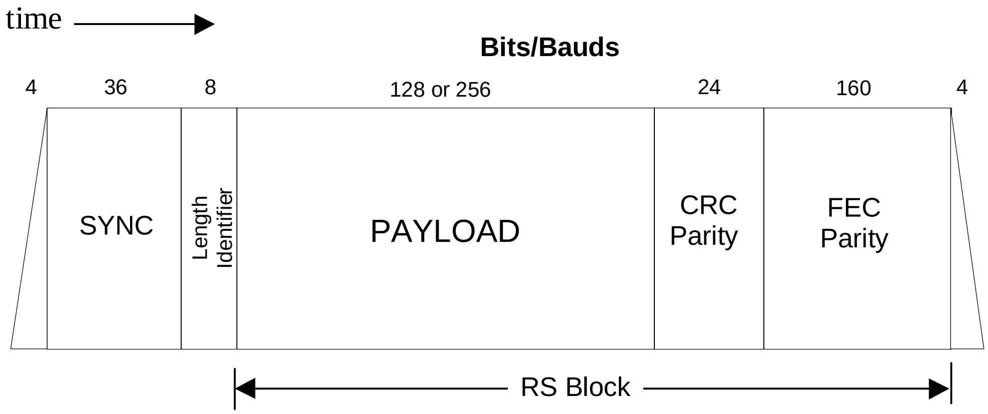
2.2.2.6 Spurious Emissions

[A specification is needed]

2.2.3 Broadcast Message Characteristics

2.2.3.1 ADS-B Message Format

The ADS-B Message format is shown in Figure 2-1. Each message element is described in detail in the subsections that follow.



ADS-B Message Format

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 "off" level to 90% power output. Ramp down time is defined as the time to decay from full power to –80 dBm at the antenna terminals. During ramp up and down, the modulating data shall be all zeroes.

2.2.3.1.2 Synchronization

Following ramp up, each data burst 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 Length Identifier

[Is length identifier necessary? If so can it be reduced to something less than 8 bits?]

2.2.3.1.4 Payload

The format and encoding of the ADS-B message payload is defined in Section 2.2.4.

2.2.3.1.5 CRC Parity

[Is this even needed anymore with the new increased FEC proposal?]

2.2.3.1.6 FEC Parity

[It would be good to assign this section to a R/S coding expert pending group decision on the waveform improvement subgroup]

2.2.3.2 Ground Uplink Message Format

[need figure and text to reflect group decision from waveform improvement subgroup]

2.2.3.2.1 Synchronization

The polarity of the bits of the synchronization sequence is reversed 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

The Payload consists of two components: the UAT-Specific Header and the Application Data as shown in Figure X

Include Figure of Uplink Message Payload fields with the following:

-Header

--Gnd Station Lat

--Gnd Station Lon

--Time Slot assignment

--Flags for Position Valid, Time Valid, Use

-Application Data

2.2.3.2.2.1 Header

2.2.3.2.2.2 Application Data

[UAT MOPS should not define any format for application data in the uplink, but only packing and delimiting of Application Protocol Data Units]

2.2.3.2.3 FEC Parity Fields

[Need FEC expert input after waveform improvement decision]

2.2.4 The ADS-B Message Payload

2.2.4.1 Basic SV Payload Format and Encoding

This subsection establishes the format and encoding of the Basic SV Payload. Table 2-2 shows the format of the individual fields of the payload. Bytes shall be transmitted in ascending order starting with byte #0. Within each byte, bits shall be transmitted in descending order beginning with bit #7. In cases where the encoding of certain fields requires support of a special procedure within the ADS-B transmitting subsystem, that procedure is specified.

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**Address Qualifier**				**Payload Type Code**			
1						. . .	A22	A23 (LSB)
2				**Aircraft Address**				
3	A0 (MSB)	A1	. . .					
4								(LSB)
5				**Longitude (WGS-84)**				
6	(N/S)							
7								(LSB)
8				**Latitude (WGS-84)**				
9	**Pos Val.**	(E/W)						
10	**1 PPS**			**NIC/NAC/NUC?**				(LSB)
11			**N-S Velocity**			(LSB)	**Turn Indicator**	
12			(LSB)	(N/S)				
13	(E/W)			**E-W Velocity**				
14				**Pressure Altitude**				(LSB)
15		**Pressure Altitude Rate**		(LSB)	(MSB)			
16	**Air/Ground State**		(Sign)					

Format of Basic SV Payload

[subsections describing the encoding of each payload field follow]

2.2.4.2 Type 0 Supplemental Payload Format and Encoding

[Input needed for this]

2.2.4.3 Type 1 Supplemental Payload Format and Encoding

[Input needed for this]

2.2.4.4 Type 2-14 Supplemental Payload Format and Encoding

These payloads will be addressed in later supplements to this document.

2.2.5 Procedures for ADS-B Message Transmission

2.2.5.1 The 1 PPS Time Mark

A 1 PPS Time Mark is used by the ADS-B transmitting subsytem to establish the transmission timing and scheduling of ADS-B messages (i.e., the UAT frame) and also may be used to indicate time of validity of position and velocity. The ADS-B transmitting subsystem shall maintain a 1 PPS UTC-based time mark by the reversionary procedure given below:

a. The primary source shall be the GPS/GNSS receiver supplying position, and velocity data. This source shall issue the 1 PPS time mark on the UTC second +/- [300 ns]. Availability of this source shall cause the ADS-B transmitting subsystem to be in Timing State 1. The leading edge of the Time Mark shall indicate the exact moment +/- 5 milliseconds that represents the time of applicability of Position and Velocity information received from the GPS/GNSS source.

b. The secondary source shall be derived from receipt of Ground Uplink messages by the receiving subsystem per Section 2.2.9.3. Lack of availability of the primary source and the availability of this secondary source shall cause the ADS-B transmitting subsystem to be in Timing State 2. The leading edge of the time mark does NOT represent a time of validity of position and velocity. [Is this timing state necessary given the guard times between ADS-B and Ground Uplink Segments? It would not be available to Class B1 installations anyway]

c. The tertiary source shall be derived from a free running clock within the ADS-B transmitting subsystem. Lack of availability of either the primary or secondary source shall cause the ADS-B transmitting subsystem to be in Timing State 3. The leading edge of the time mark does NOT represent a time of validity of position and velocity. ADS-B transmissions shall not encroach on the Ground Uplink segment for at least 1 hour after entry into Timing State 3

NOTE: Timing State 1 is always the preferred condition. Entry into Timing State 2 or 3 represents a failure of the primary GPS/GNSS navigation source. These reversionary Timing States exist for the following reasons:

-support ADS-B message transmission using an alternate source of position and velocity, if available

-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 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)

2.2.5.2 Scheduling of ADS-B Messages

2.2.5.2.1 Message Transmission Epoch

ADS-B message transmissions shall be scheduled based on a message transmission epoch composed of exactly four UAT frame intervals.

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

2.2.5.2.2 Message Transmission Rate

The message scheduling mechanism shall provide the message transmission rates specified in Table X below based on the availability of data to the ADS-B transmitting subsystem.

ADS-B Message Contents and Transmission Rates

				Transmission Rate per Epoch			
Message Type	**Payload Type Code**	**Message Length**	**Contents**	All Class B2 (non-aircraft transmitters)	Standard Info Bdcst for All Class A0, A1, B1	Standard info Bdcst for Class A2, A3	<Future Applications>
Basic	1111	Short	SV *only*	4	3	1	
Extended Type 0	0000	Long	SV *plus* Supplemental Type 0 payload		1	1	
Extended Type 1	0001	Long	SV *plus* Supplemental Type 1 payload			2	
Extended Type 2-14	0010-1110	Long	SV plus Supplemental externally supplied payload (128 bits) provided "on condition" each epoch				

2.2.5.2.3 Transmitter Antenna Diversity

For installations that support ADS-B message transmission from dual (diversity) antennas, the installation shall be configured to transmit through each antenna at one half the rate specified in Section 2.2.5.2.2:

a. On a total message basis per epoch, and

b. Such that each message type scheduled is transmitted from both antennas at least once every two transmission epochs

NOTE: Antenna diversity could be implemented with dual redundant transmitters each connected to its dedicated antenna or from a single transmitter with antenna switching.

2.2.5.2.4 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"

2.2.5.3 Message Transmit Timing

2.2.5.3.1 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. Suppose the previous number is R(m-1) and

N(1) = 12 L.S.B.'s of the current latitude

N(2) = 12 L.S.B.'s of the current longitude

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 initial R(m) shall be zero

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

NOTE: This algorithm provides anonymity to the aircraft and ensures, with very high probability, that no two aircraft will repeatedly choose the same MSO's.

2.2.5.3.2 Relationship of the MSO to the Modulated Data

The leading edge of the first baud of the synchronization sequence shall coincide with the Time Mark offset by 250 usec times the MSO value determined from Section 2.2.5.3.1 to within +/- [250 nanoseconds].

NOTE: This is required to support ADS-B range validation by the receiver

2.2.5.4 Latency of ADS-B Message Payload Fields

2.2.5.4.1 UTC Coupled and Non-UTC Coupled Cases for Position and Velocity

The specification of latency requirements for position and velocity cover two distinct cases:

a. The UTC Coupled case is the condition where the position and velocity data are computed and valid at the 1 PPS UTC time mark also provided by the same navigation system. This case will also correspond to the ADS-B transmitting subsystem being in Timing State 1

b. The Non-UTC Coupled case is the condition where position and velocity data come from an alternate navigation source (non-GPS/GNSS) where UTC time is not available. This case will correspond to the ADS-B transmitting subsystem being in Timing State 2 or 3

2.2.5.4.2 Position and Velocity (UTC Coupled, Timing State 1)

At the time of ADS-B message transmission as determined in Section 2.2.5.3.1, position and velocity information encoded in the Latitude, Longitude, N-S Velocity, and E-W Velocity fields shall be valid as of the immediately previous 1 PPS Time Mark. Specifically, NO extrapolation to the time of transmission is to be performed.

2.2.5.4.3 Position and Velocity (Non-UTC Coupled)

[To be provided]

2.2.5.4.4 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 containing that field. Table 2-15 below shows the value of ***X*** for each field.

Latency of ADS-B Message Fields

ADS-B Message Payload Field	Value of X (Section 2.2.5.4.4)
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	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 changable
Flight ID subfield	1000
Message Start Opportunity	Must use value established by ADS-B transmitting subsystem for the current frame

2.2.6 Receiver Characteristics

2.2.6.1 Sensitivity

A maximum desired signal level of –93 dBm applied at the antenna terminals shall produce a message success rate of 90% or better.

2.2.6.2 Frequency Capture Range

The receiver shall be capable of successful message detection with the maximum permitted signal frequency offset plus air-air doppler at 1200 knots closure/opening.

2.2.6.3 Baud Rate Offset Tolerance

A 90% message success rate shall be achieved when the desired signal is subject to a symbol rate offset of +/-100 ppm.

2.2.6.4 Desired Signal Dynamic Range

The receiver shall continue to achieve a 90% message success rate when the desired signal level is increased to [-10 dBm].

2.2.6.5 Back-to-Back Message Reception

[Test to establish minimum receiver recovery time. How to specify and test? Is it important? Is a separate requirement necessary for ADS-B and Ground Uplink?]

2.2.6.6 Amplitude Discrimination of Overlapping ADS-B Messages

A 90% or better message success rate 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 [6 dB] above the weaker signal under the following conditions:

a. the stronger signal and weaker signal align within +/- 5 usec

b. the weaker signal precedes the stronger signal by 100 usec

2.2.6.7 Rejection of Out-of-Band Signals

A 90% message success rate shall be achieved when an unmodulated continuous wave interfering signal of [-30 dBm] is combined with the desired signal at –70 dBm. The interfering signal shall be applied separately + 2 and – 2 MHz offset from f_0.

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

2.2.6.8 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]

2.2.6.9 Message Time of Receipt

The receiver shall declare a Message Time Of Receipt (MTOR) and include the MTOR value as part of the report issued to the on-board application systems. The MTOR value shall be reported to within [+/- 200 nanoseconds] of the actual value with 95% confidence.

NOTE: The MTOR value need only be expressed in terms of offset from the 1 PPS UTC time mark just prior to reception.

2.2.6.10 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 this purpose

2.2.7 Report Generation Requirements

Reports shall be generated for on-board applications only in response to a received message. Exactly one report shall be generated for each message successfully received.

2.2.7.1 Report Generation on Receipt of ADS-B Message

2.2.7.1.1 Message Integrity Requirements

No ADS-B message payload shall be forwarded as a report unless the decoding of the CRC parity and FEC parity EACH indicate that there are NO detected errors.

2.2.7.1.2 Report Generation and Integrity

a. Upon receipt of an ADS-B message with no detected errors, a report shall be issued that includes the unaltered payload of the message received and the MTOR (Section 2.2.6.9).

b. Reports shall be issued from the UAT receiver to on-board application systems with an integrity check at least equivalent to a CRC-16.

2.2.7.2 Report Generation on Receipt of Ground Uplink Message

2.2.7.2.1 Message Integrity Requirements

a. Each R/S block of the Ground Uplink message shall be individually examined for errors. The payload of each block shall be declared as valid only if there are NO detected errors resulting from FEC Parity decoding.

b. The Ground Uplink message shall be declared as valid only if payloads within EACH individiual R/S Block are declared valid from a) above.

2.2.7.2.2 Report Generation and Integrity

If the requirements of Section 2.2.7.2.1 are met, the Ground Uplink Message payload is created with the steps described below:

a. The individual R/S block payloads are concatenated in the order received.

b. A report shall be issued that includes the unaltered payload of the message received and the MTOR (Section 2.2.6.9).

a. Reports shall be issued from the UAT receiver to on-board application systems with an integrity check at least equivalent to a CRC-16

2.2.8 Receiver Subsystem Throughput Requirements

2.2.8.1 Input Message Capacity

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

2.2.8.2 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"]

2.2.9 Special Requirements for Transceiver Implementations

2.2.9.1 Transmit-Receive Turnaround Time

The receiver shall be capable of receiving a desired signal within [2] ms of the ramp down of a transmitted signal.

2.2.9.2 Receive-Transmit Turnaround Time

The transmitter shall be capable of commencing transmission of an ADS-B message within [2] ms after arrival of a successfully received desired signal

2.2.9.3 Estimated 1 PPS

In the absence of an external 1 PPS UTC time mark, the receiver shall provide a 1 PPS UTC estimated time mark to the transmitter when at least one Ground Uplink message is received per UAT frame. This estimated time mark shall be sufficiently accurate to prevent ADS-B message transmissions from straying outside the ADS-B segment as long as the Ground Uplink messages are being received.

[When should this be a requirement? It seems this capability matters only if the installation supports an alternate navigation input to ADS-B]