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Standards and Recommended Practices for the Universal Access Transceiver (UAT)

Draft Revision 5.0

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2 Oct 2002/v0.2	Incorporate changes from review and discussion at Langen meeting
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15 Jan 2003/v1.1	Updated during UAT Subgroup Meeting #2 13-16 January 2003 in Montreal
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16 Sept 2003/v1.6	Incorporated comments from 12 Sept telecon • Delete and replace note in Section 12.1.2.3 • Add Note 3 to section 12.1.2.6 • Add final sentence to existing Note 4 of Section 12.3.2.2 • Reverse order of Sections 12.3.2.4 and 12.3.2.3 • Clarify that reference is to the vertical eye opening in Section 12.4.3 • Various editorial corrections
21 Oct 2003/V2.0	As accepted during the review and incorporation of changes that were identified during ACP WG-C/6, Toulouse, 20-24 October 2003
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3 March 2004/V2.2	As revised during the UAT Subgroup Meeting #5 in Montreal 1-4 March 2004.
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9 July 2004/V3.1	Change Bit Periods from 4x4 to 2x6 and 6x2 in the text of 12.1.2.6 and graphically in Figure 2, as agreed to by RTCA WG-5 during Meeting 21 while reviewing final comments on the UAT MOPS Revision A (RTCA/DO-282A)
16 Sept 2004/V3.2	Changes made during UAT Subgroup Meeting #6 in Madrid, 15-17 Sept. 2004
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2 March 2005/V4.2	As modified during the review during the UAT Subgroup Meeting #9 in Montreal, 28 February – 2 March 2005.
17 March 2005/V4.3	As modified during the review during the UAT Subgroup Meeting #10 in Montreal, 14-17 March 2005.
4 April 2005/V5.0	As reviewed and approved during the ICAO ACP WG-C/9 in Montreal, 4 – 8 April 2005.

12.0 CHAPTER 12. UNIVERSAL ACCESS TRANSCEIVER (UAT)

12.1 DEFINITIONS AND OVERALL SYSTEM CHARACTERISTICS

12.1.1 Definitions

UAT: Universal Access Transceiver (UAT) is a broadcast data link operating on 978 MHz, with a modulation rate of 1.041667 Mbps.

UAT ADS-B Message: UAT ADS-B Messages are broadcast once per second by each aircraft to convey State Vector and other information. UAT ADS-B Messages can be in one of two forms depending on the amount of information to be transmitted in a given second: the *Basic UAT ADS-B Message* or the *Long UAT ADS-B Message* (see Section §12.4.4.1 for definition of each). UAT Ground Stations can support Traffic Information Service-Broadcast (TIS-B) through transmission of individual ADS-B Messages in the ADS-B segment of the UAT frame.

UAT Ground Uplink Message: The UAT Ground Uplink Message is used by Ground Stations to broadcast, within the Ground Segment of the UAT Frame, flight information such as text and graphical weather data, advisories, and other aeronautical information, to aircraft that are in the service volume of the Ground Station (see Section §12.4.4.2 for further details).

Standard Receiver: A general purpose UAT receiver satisfying the minimum rejection requirements of interference from adjacent frequency Distance Measuring Equipment (DME) (see Section §12.3.2.2 for further details).

High Performance Receiver: A UAT receiver with enhanced selectivity to further improve the rejection of adjacent frequency DME interference (see Section §12.3.2.2 for further details).

Optimum Sampling Point: The optimum sampling point of a received UAT bit stream is at the nominal center of each bit period, when the frequency offset is either plus or minus 312.5 kHz.

Power Measurement Point (PMP): A cable connects the antenna to the UAT equipment. The PMP is the end of that cable that attaches to the antenna. All power measurements are considered as being made at the PMP unless otherwise specified. The cable connecting the UAT equipment to the antenna is assumed to have 3 dB of loss.

Successful Message Reception (SMR): The function within the UAT receiver for declaring a received message as valid for passing to an application that uses received UAT messages. See Section 4.0 of the Manual on the UAT Detailed Technical Specifications for a detailed description of the procedure to be used by the UAT receiver for declaring successful message reception.

Pseudorandom Message Data Block: Several UAT requirements state that performance will be tested using pseudorandom message data blocks. Pseudorandom message data blocks should have statistical properties that are nearly indistinguishable from those of a true random selection of bits. For instance, each bit should have (nearly) equal probability of being a ONE or a ZERO, independent of its neighboring bits. There should be a large number of such pseudorandom message data blocks for each message type (Basic ADS-B, Long ADS-B or Ground Uplink) to provide sufficient independent data for statistical performance measurements. See Section 2.3 of the Manual on the UAT Detailed Technical Specifications for an example of how to provide suitable pseudorandom message data blocks.

Service Volume: A part of the facility coverage where the facility provides a particular service in accordance with relevant SARPs and within which the facility is afforded frequency protection.

12.1.2 UAT Overall System Characteristics of Aircraft and Ground Stations

Note: *Details on technical requirements related to the implementation of UAT SARPs are contained in the Manual on the UAT Detailed Technical Specifications. The UAT Implementation Manual provides additional guidance material.*

12.1.2.1 Transmission Frequency

The transmission frequency **shall** be 978 MHz.

12.1.2.2 Frequency Stability

The radio frequency of the UAT equipment **shall** not vary more than ±0.002% (20 ppm) from the assigned frequency.

12.1.2.3 Transmit Power

12.1.2.3.1 Transmit Power Levels

UAT equipment **shall** operate at one of the power levels shown in Table 1 below.

<u>Table 1:</u> Transmitter Power Levels

Transmitter Type	Minimum Power at PMP	Maximum Power at PMP	Intended Minimum Air-to-Air Ranges
Aircraft (Low)	7 watts (+38.5 dBm)	18 watts (+42.5 dBm)	20 NM
Aircraft (Medium)	16 watts (+42 dBm)	40 watts (+46 dBm)	40 NM
Aircraft (High)	100 watts (+50 dBm)	250 watts (+54 dBm)	120 NM
Ground Station	Specified by the service provider to meet local requirements within the constraint of Section §12.1.2.3.2		

Notes:

1. *The 3 different levels listed for the avionics are available to support applications with varying range requirements. See the discussion of UAT aircraft Equipage Classes in Section 2.4.2 of the UAT Implementation Manual.*

2. *The intended minimum air-to-air ranges are for high-density air traffic environments. Larger air-to-air ranges will be achieved in low-density air traffic environments.*

12.1.2.3.2 Maximum Power

The maximum EIRP for a UAT aircraft or Ground Station **shall** not exceed +58 dBm.

Note: *For example, the maximum EIRP listed above could result from the maximum allowable aircraft transmitter power shown in Table 1 with a maximum antenna gain of 4 dBi.*

12.1.2.3.3 Transmit Mask

The spectrum of a UAT ADS-B Message transmission modulated with pseudorandom Message Data Blocks (MDB) **shall** fall within the limits specified in Table 2 when measured in a 100 kHz bandwidth.

Note: *Figure 1 is a graphical representation of Table 2.*

Table 2: UAT Transmit Spectrum

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

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

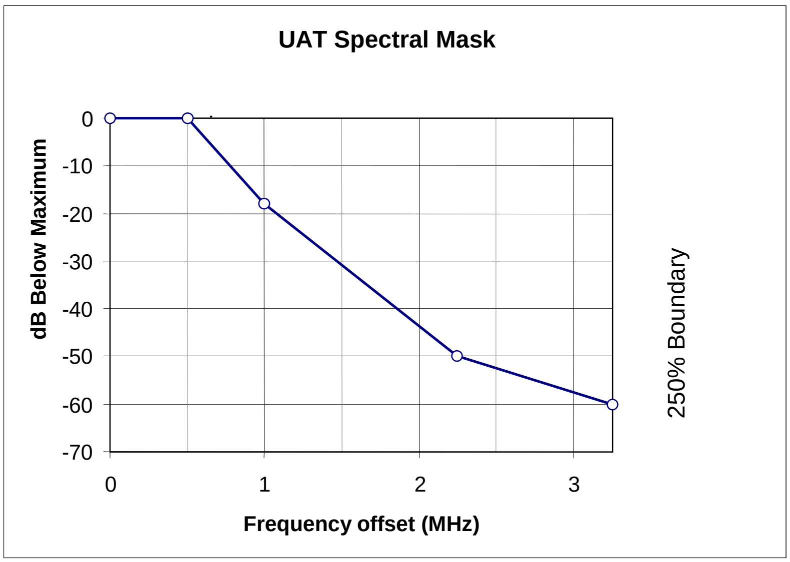


Figure 1: UAT Transmit Spectrum

Notes:

1. *99% of the power of the UAT spectrum is contained in 1.3 MHz (±0.65 MHz). This is roughly equivalent to the 20 dB bandwidth.*
2. *Spurious emissions requirements begin at ±250% of the 1.3 MHz value, therefore the transmit mask requirement extends to ±3.25 MHz.*

12.1.2.4 Spurious Emissions

Spurious emissions **shall** be kept at the lowest value which the state of the technique and the nature of the service permit.

Note: *Appendix 3 of the ITU Radio Regulations requires that transmitting stations shall conform to the maximum permitted power levels for spurious emissions or for unwanted emissions in the spurious domain.*

12.1.2.5 Polarization

The design polarization of emissions **shall** be vertical.

12.1.2.6 Time/Amplitude Profile of UAT Message Transmission

The Time/Amplitude profile of a UAT Message Transmission **shall** meet the following requirements, in which the *reference time* is defined as the beginning of the first bit of the synchronization sequence (see §12.4.4.1.1, §12.4.4.2.1) appearing at the output port of the equipment.

Notes:

1. *All power requirements for subparagraphs "**a**" through "**f**" below apply to the PMP. For installations that support transmitter diversity, the RF power output on the non-selected antenna port should be at least 20 dB below the level on the selected port.*

2. *All power requirements for subparagraphs "**a**" and "**f**" assume a 300 kHz measurement bandwidth. All power requirements for subparagraphs "**b**," "**c**," "**d**" and "**e**" assume a 2 MHz measurement bandwidth.*

3. *The beginning of a bit is ½ bit period prior to the optimum sample point.*

4. *These requirements are depicted graphically in Figure 2.*

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

   Note: *This unwanted radiated power restriction is necessary to ensure that the UAT Transmitting Subsystem does not prevent closely located UAT receiving equipment on the same aircraft from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment at the PMP exceeds 20 dB.*

b. Between 8 and 6 bit periods prior to the reference time, the RF output power at the PMP **shall** remain at least 20 dB below the minimum power requirement for the UAT equipment class.

   Note: *Guidance on definition of UAT equipment classes is provided in the UAT Implementation Manual.*

c. During the Active state, defined as beginning at the reference time and continuing for the duration of the message, the RF output power at the PMP **shall** be greater than or equal to the minimum power requirement for the UAT equipment class.

d. The RF output power at the PMP **shall not** exceed the maximum power for the UAT equipment class at any time during the Active state.

e. Within 6 bit periods after the end of the Active state, the RF output power at the PMP **shall** be at a level at least 20 dB below the minimum power requirement for the UAT equipment class.

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

Note: *This unwanted radiated power restriction is necessary to ensure that the Transmitting Subsystem does not prevent closely located UAT receiving equipment on the same aircraft from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment at the PMP exceeds 20 dB.*

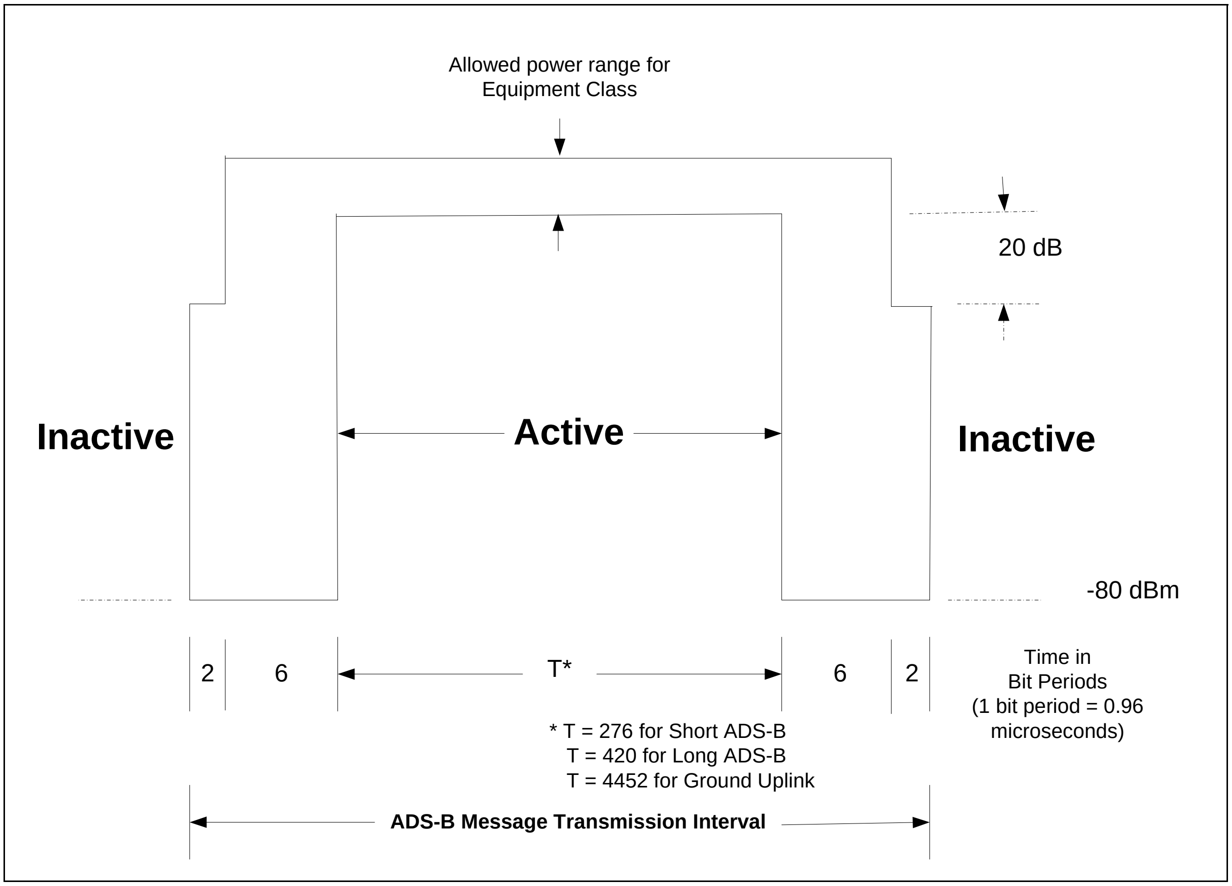


Figure 2: Time/Amplitude Profile of UAT Message Transmission

12.1.3 Mandatory Carriage Requirements

Requirements for mandatory carriage of UAT equipment **shall** be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment, including the appropriate lead time.

Note: *No changes will be required to aircraft systems or ground systems operating solely in regions not using UAT.*

12.2 SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

12.2.1 Ground Station Transmitting Function

12.2.1.1 Ground Station Transmitter Power

Recommendation: *— The effective radiated power should be such as to provide a field strength of at least 280 microvolts per metre (minus 97 dBW/m^2) within the service volume of the facility on the basis of free-space propagation.*

Note: *This is determined on the basis of delivering a –91 dBm (corresponds to 200 microvolts per metre) signal level at the PMP (assuming an omni-directional antenna). The 280 µV/m recommendation corresponds to the delivery of a –88 dBm signal level at the PMP of the receiving equipment. The 3 dB difference between –88 dBm and –91 dBm provides margin for excess path loss over free-space propagation.*

12.2.2 Ground Station Receiving Function

Note: *An example Ground Station Receiver is discussed in Section 2.5 of the UAT Implementation Manual, with UAT air-to-ground performance estimates consistent with use of that receiver provided in Appendix B of that Manual.*

12.3 SYSTEM CHARACTERISTICS OF THE AIRCRAFT INSTALLATION

12.3.1 Aircraft Transmitting Function

12.3.1.1 Aircraft Transmitter Power

The effective radiated power **shall** be such as to provide a field strength of at least 225 microvolts per metre (minus 99 dBW/m^2) on the basis of free-space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated. Transmitter power **shall not** exceed 54 dBm at the PMP.

Notes:

1. *The above field strength is determined on the basis of delivering a –93 dBm (corresponds to 160 microvolts per metre) signal level at the PMP (assuming an omni-directional antenna). The 3 dB difference between 225 µV/m and 160 µV/m provides margin for excess path loss over free-space propagation when receiving a Long UAT ADS-B Message. A 4 dB margin is provided when receiving a Basic UAT ADS-B Message.*

2. *Various aircraft operations may have different air-air range requirements depending on the intended ADS-B function of the UAT equipment. Therefore different installations may operate at different power levels (see §12.1.2.3.1).*

12.3.2 Receiving Function

12.3.2.1 Receiver Sensitivity

12.3.2.1.1 Long UAT ADS-B Message as Desired Signal

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

a. When the desired signal is of nominal modulation (i.e., FM deviation is 625 KHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±1200 knots.

b. When the desired signal is of maximum modulation distortion allowed in Section §12.4.3, at the nominal transmission frequency ±1 PPM, and subject to relative Doppler shift at ±1200 knots.

Note: *The receiver criteria for Successful Message Reception of UAT ADS-B Messages are provided in Section 4 of the Manual on the UAT Detailed Technical Specifications.*

12.3.2.1.2 Basic UAT ADS-B Message as Desired Signal

A desired signal level of –94 dBm applied at the PMP **shall** produce a rate of Successful Message Reception of 90% or better under the following conditions:

a. When the desired signal is of nominal modulation (i.e., FM deviation is 625 KHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±1200 knots.

b. When the desired signal is of maximum modulation distortion allowed in Section §12.4.3, at the nominal transmission frequency ±1 PPM, and subject to relative Doppler shift at ±1200 knots.

Note: *The receiver criteria for Successful Message Reception of UAT ADS-B Messages are provided in Section 4 of the Manual on the UAT Detailed Technical Specifications.*

12.3.2.1.3 UAT Ground Uplink Message as Desired Signal

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

a. When the desired signal is of nominal modulation (i.e., FM deviation is 625 KHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±850 knots.

b. When the desired signal is of maximum modulation distortion allowed in Section §12.4.3, at the nominal transmission frequency ±1 PPM, and subject to relative Doppler shift at ±850 knots.

Notes:

1. *The receiver criteria for Successful Message Reception of UAT Ground Uplink Messages is provided in Section 4 of the Manual on the UAT Detailed Technical Specifications.*

2. *This requirement ensures the bit rate accuracy supporting demodulation in the UAT equipment is adequate to properly receive the longer UAT Ground Uplink Message.*

12.3.2.2 Receiver Selectivity

Notes:

1. *The undesired signal used is an unmodulated carrier applied at the frequency offset.*

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

3. *It is assumed that ratios in between the specified offsets will fall near the interpolated value.*

4. *The desired signal used is a UAT ADS-B Long Message at -90 dBm at the PMP, to be received with a 90% Successful Message Reception Rate.*

5. *The tolerable co-channel continuous wave interference power level for aircraft UAT Receivers is assumed to be -101 dBm or less at the PMP.*

6. *See Section §2.4.2 of the UAT Implementation Manual for a discussion of when a High Performance Receiver is desirable.*

a. Standard receivers **shall** meet the selectivity characteristics given in Table 3:

<u>Table 3:</u> Standard Receiver Rejection Ratios

Frequency Offset from Center	Minimum Rejection Ratio (Undesired/Desired level in dB)
-1.0 MHz	10
+1.0 MHz	15
(±) 2.0 MHz	50
(±) 10.0 MHz	60

<u>Note:</u> *It is assumed that ratios in between the specified offsets will fall near the interpolated value.*

b. High performance receivers **shall** meet the more stringent selectivity characteristics given in Table 4 below:

<u>Table 4:</u> High Performance Receiver Rejection Ratios

Frequency Offset from Center	Minimum Rejection Ratio (Undesired/Desired level in dB)
-1.0 MHz	30
+1.0 MHz	40
(±) 2.0 MHz	50
(±) 10.0 MHz	60

<u>Note:</u> *See Section §2.4.2 of the UAT Implementation Manual for guidance material on the implementation of High Performance Receivers.*

12.3.2.3 Receiver Desired Signal Dynamic Range

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

<u>Note:</u> *The value of –10 dBm represents 120-foot separation from an aircraft transmitter transmitting at maximum allowed power.*

12.3.2.4 Receiver Tolerance to Pulsed Interference

Note: *All power level requirements in this section are referenced to the PMP.*

a. For Standard and High Performance receivers the following requirements **shall** apply:

1. The receiver **shall** be capable of achieving 99% SMR of Long UAT ADS-B Messages when the desired signal level is between –90 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at either 12 or 30 microseconds pulse spacing at a level of –36 dBm for any 1 MHz DME channel frequency between 980 MHz and 1213 MHz inclusive.

2. Following a 21 microsecond pulse at a level of ZERO (0) dBm and at a frequency of 1090 MHz, the receiver **shall** return to within 3 dB of the specified sensitivity level (see §12.3.2.1) within 12 microseconds.

b. For the Standard Receiver the following additional requirements **shall** apply:

1. The receiver **shall** be capable of achieving 90% SMR of Long UAT ADS-B Messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –56 dBm and a frequency of 979 MHz.

2. The receiver **shall** be capable of achieving 90% SMR of Long UAT ADS-B Messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –70 dBm and a frequency of 978 MHz.

c. For the High Performance receiver the following additional requirements **shall** apply:

1. The receiver **shall** be capable of achieving 90% SMR of Long UAT ADS-B Messages when the desired signal level is between–87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –43 dBm and a frequency of 979 MHz.

2. The receiver **shall** be capable of achieving 90% SMR of Long UAT ADS-B Messages when the desired signal level is between–87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3,600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –79 dBm and a frequency of 978 MHz.

12.4 PHYSICAL LAYER CHARACTERISTICS

12.4.1 Modulation Rate

The modulation rate **shall** be 1.041667 Mbps with a tolerance for aircraft transmitters of ±20 PPM and a tolerance for ground transmitters of ±2 PPM.

Note: *The tolerance on the modulation rate is consistent with the requirement on modulation distortion (See §12.4.3.).*

12.4.2 Modulation Type

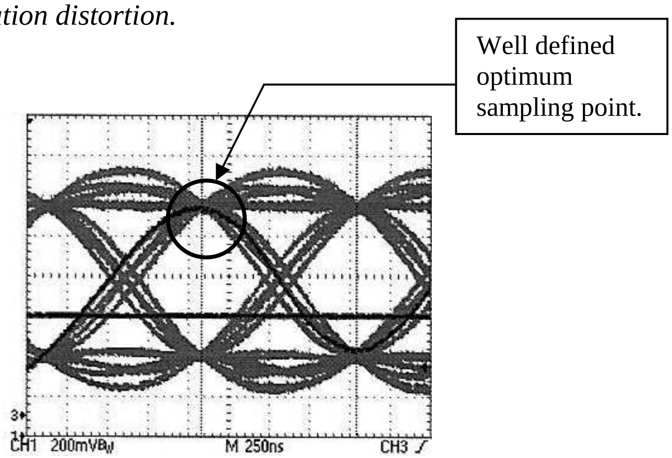
a. Data **shall** be modulated onto the carrier using binary Continuous Phase Frequency Shift Keying. The modulation index, *h*, **shall** be no less than 0.6;

b. A binary ONE (1) **shall** be indicated by a shift up in frequency from the nominal carrier frequency and a binary ZERO (0) by a shift down from the nominal carrier frequency.

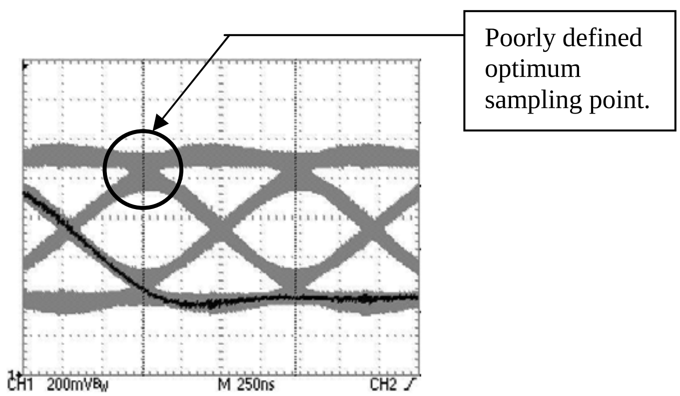
Notes:

1. Filtering of the transmitted signal (at base band and/or after frequency modulation) will be required to meet the spectral containment requirement of Section §12.1.2.3.3. This filtering may cause the deviation to exceed these values at points other than the optimum sampling points.

2. *Because of the 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 ideal eye diagram is a superposition of samples of the (undistorted) post detection waveform shifted by multiples of the bit period (0.96 microseconds). 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. An example "eye diagram" can be seen in Figure 3. The timing of the points where the lines converge defines the "optimum sampling point." Figure 4 shows an eye pattern that has been partially closed by modulation distortion.*



<u>Figure 3:</u> Ideal eye diagram



<u>Figure 4:</u> Distorted eye diagram

12.4.3 Modulation Distortion

a. For aircraft transmitters, the minimum vertical opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) **shall** be no less than 560 kHz when measured over an entire Long UAT ADS-B Message containing pseudorandom Message Data Blocks.

b. For ground transmitters, the minimum vertical opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) **shall** be no less than 560 kHz when measured over an entire UAT Ground Uplink Message containing pseudorandom Message Data Blocks.

c. For Aircraft transmitters, the minimum horizontal opening of the eye diagram of the transmitted signal (measured at 978 MHz) **shall** be no less than 0.624 µs (0.65 symbol periods) when measured over an entire Long UAT ADS-B Message containing pseudorandom Message Data Blocks.

d. For ground transmitters, the minimum horizontal opening of the eye diagram of the transmitted signal (measured at 978 MHz) **shall** be no less than 0.624 µs (0.65 symbol periods) when measured over an entire UAT Ground Uplink Message containing pseudorandom Message Data Blocks.

Notes:

1. *Section §12.4.4 defines the UAT ADS-B Message types.*

2. *The ideal eye diagram is a superposition of samples of the (undistorted) post detection waveform shifted by multiples of the bit period (0.96 microseconds).*

12.4.4 Broadcast Message Characteristics

The UAT system **shall** support two different message types: the UAT ADS-B Message and the UAT Ground Uplink Message.

12.4.4.1 UAT ADS-B Message

The Active portion (see §12.1.2.6) of a UAT ADS-B Message **shall** contain the following elements, in the following order:

- Bit Synchronization,
- Message Data Block,
- FEC parity

12.4.4.1.1 Bit Synchronization

The first element of the Active portion of the UAT ADS-B Message **shall** be a 36-bit synchronization sequence. For the UAT ADS-B Messages the sequence **shall** be:

111010101100110111011010010011100010

with the left-most bit transmitted first.

12.4.4.1.2 The Message Data Block

The second element of the Active portion of the UAT ADS-B Message **shall** be the Message Data Block. There **shall** be two lengths of UAT ADS-B Message Data Blocks supported. The Basic UAT ADS-B Message **shall** have a 144-bit Message Data Block and the Long UAT ADS-B Message **shall** have a 272-bit Message Data Block.

Note: *The format, encoding and transmission order of the Message Data Block element is provided in Section §2.1 of the Manual on the UAT Detailed Technical Specifications.*

12.4.4.1.3 FEC Parity

The third and final element of the Active portion of the UAT ADS-B Message **shall** be the FEC parity.

12.4.4.1.3.1 Code Type

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

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

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

b. Long UAT ADS-B Message: Parity **shall** be a RS (48, 34) code.

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

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

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

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

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

where:

P = 131 for RS (30,18) code,
P = 133 for RS (48,34) code, and
α is a primitive element of a Galois field of size 256 (i.e., GF(256)).

12.4.4.1.3.2 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 Data Block.

12.4.4.2 UAT Ground Uplink Message

The Active portion of a UAT Ground Uplink Message **shall** contain the following elements, in the following order:

- bit synchronization,
- interleaved Message Data Block and FEC parity.

12.4.4.2.1 Bit Synchronization

The first element of the Active portion of the UAT Ground Uplink Message **shall** be a 36-bit synchronization sequence. For the UAT Ground Uplink Message the sequence **shall** be:

000101010011001000100101101100011101

with the left-most bit transmitted first.

12.4.4.2.2 Interleaved Message Data Block and FEC Parity

12.4.4.2.2.1 Message Data Block (before interleaving and after de-interleaving)

The UAT Ground Uplink Message **shall** have 3456 bits of Message Data Block. These bits are divided into 6 groups of 576 bits. FEC is applied to each group as described in §12.4.4.2.2.2.

Note: *Further details on the format, encoding and transmission order of the UAT Ground Uplink Message Data Block are provided in Section §2.2 of the Manual on the UAT Detailed Technical Specifications.*

12.4.4.2.2.2 FEC Parity (before interleaving and after de-interleaving)

12.4.4.2.2.2.1 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 for each of the six blocks **shall** be a RS (92,72) code.

Notes:

1. *Section §12.4.4.2.2.3 provides details on the interleaving procedure.*

2. *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 UAT Ground Uplink Message allows additional robustness against 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, and
α is a primitive element of a Galois field of size 256 (i.e., GF(256)).

12.4.4.2.2.2.2 Transmission Order of FEC Parity

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

12.4.4.2.2.3 Interleaving Procedure

UAT Ground Uplink Messages **shall** be interleaved and transmitted by the Ground Station, as listed below:

a. Interleaving Procedure: The interleaved Message Data Block and FEC Parity consists of 6 interleaved Reed-Solomon blocks. The interleaver is represented by a 6x92 matrix, where each entry is a RS 8-bit symbol. Each row comprises a single RS (92,72) block as shown in Table 5. In Table 5, 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.

<u>Table 5:</u> Ground Uplink Interleaver Matrix

RS Block	MDB Byte #						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

<u>Note:</u> *In Table 5, Message Data Block Byte #1 through #72 are the 72 bytes (8 bits each) of Message Data Block 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. <u>Transmission Order</u>: 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.

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

12.5 Guidance Material

<u>Notes:</u>

1. *The Manual on the UAT Detailed Technical Specifications provides: details on UAT ADS-B Message Data Blocks and formats, procedures for operation of UAT Transmitting Subsystems, and avionics interface requirements with other aircraft systems.*

2. *The UAT Implementation Manual provides information on fundamentals of UAT system operation, description of a range of example avionics equipment classes and their applications, guidance on UAT aircraft and Ground Station installation aspects, and detailed information on UAT system performance simulation.*

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