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Universal Access Transceiver (UAT)

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FOREWORD

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TABLE OF CONTENTS

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1 Introduction

1.1 Outline of the Manual

This document contains

Section 1 of this document provides

Section 2 contains

Section 3 describes

Section 4 describes

Appendix A describes assumptions made in this document on future UAT Ground Infrastructure. These assumptions have been used to estimate UAT performance when supporting air-ground applications of ADS-B.

Appendix B contains an Example ADS-B Message Coding for the UAT System.

Appendix C describes the Standard Interference Environments that have been used to estimate UAT System performance. These environments are based upon internationally-developed traffic scenarios for future high and low density airspace and near-worst-case estimates of interference caused by other systems transmitting on or near the UAT intended operational frequency of 978 MHz.

Appendix D details the UAT System Performance Simulation Results, which summarizes results of UAT System performance evaluations in the Standard Interference Environments of Appendix C. Air-to-air and air-ground system performance is assessed. All performance estimates reflect broadcast of all State Vector (SV), Mode Status (MS), and Intent information (including Trajectory Change Reports) defined in the ADS-B MASPS, RTCA/DO-242A.

Appendix E discusses UAT Timing Performance, an aspect of the UAT System that underpins, for example, potential use of UAT for supplementary ranging and positioning.

1.2 Background

1.3 Definitions

2 Operating Concepts

2.1 Applications Supported

2.1.1 ADS-B

ADS-B is a system by which aircraft, certain equipped surface vehicles, and fixed ground locations can share (i.e., broadcast) position, velocity, and other information with one another. With such information made available by ADS-B from other proximate aircraft, it is possible to establish the relative position and movement of those aircraft with reference to one's own aircraft. It is also possible for ground-based facilities to monitor ADS-B broadcasts to enable basic surveillance capabilities, or to supplement existing surveillance systems. Other data that are shared using ADS-B include information related to the aircraft's intended flight path ("intent" data), aircraft type, and other information.

ADS-B is automatic in the sense that no pilot or controller action is required for the information to be broadcast. It is dependent surveillance in the sense that the aircraft surveillance-type information is derived from on-board navigation equipment.

ADS-B is considered to be a key enabling technology to enhance safety and efficiency in airspace operations. These include basic applications, such as the use of ADS-B to enhance the pilot's visual acquisition of other nearby aircraft, as well as more advanced applications, such as enabling enhanced closely spaced parallel approach operations. Other applications involving airport surface operations, improved surveillance in non-radar airspace, and advanced conflict management are also described. Fleet management and search and rescue are also applications for ADS-B.

2.1.2 TIS-B

Traffic Information Service - Broadcast (TIS-B) is a ground-based service to ADS-B-equipped aircraft to provide surveillance data on non-ADS-B-equipped aircraft. TIS-B may also be used in ADS-B implementations involving multiple ADS-B data links to provide a cross-link—or "gateway"—between ADS-B equipped aircraft using different data links. The service is intended to provide ADS-B-equipped aircraft with a more-complete traffic picture in situations where not all aircraft are equipped with ADS-B (or with the same ADS-B data link).

As commonly envisioned, TIS-B involves three major functions. First, another source of surveillance information on non-ADS-B aircraft (such as Secondary Surveillance Radar (SSR)) must be available. Second, this surveillance information must be converted and processed so as to be usable by ADS-B-equipped aircraft. And third, a broadcast facility and protocol is necessary to convey this information to ADS-B-equipped aircraft.

2.1.3 FIS-B

FIS-B is the ground-to-air broadcast of non-control, advisory information needed by pilots to operate more safely and efficiently in the National Airspace System and in international airspace. FIS provides to pilots the necessary weather graphics (e.g., NEXRAD reflectivity) and text (e.g., METAR and TAF), Special Use Airspace information, Notices to Airmen, and other information.

2.1.4 UAT Broadcast Connectivity

Figure 2-2 below shows the connectivity supported by UAT for ADS-B air-air, ADS-B air-ground, TIS-B and FIS-B.

{insert figure}

Figure 2-2. UAT Connectivity

2.2 Channel and Waveform Description

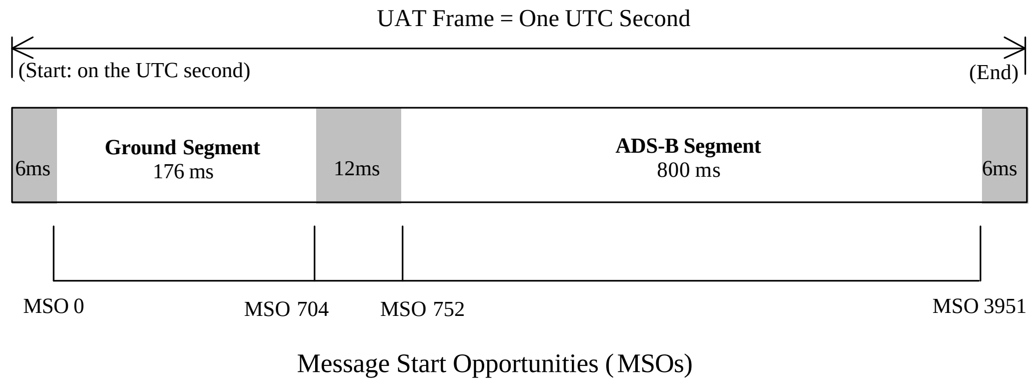
The UAT employs a single common global channel to support the multiple services of ADS-B , TIS-B and FIS-B. The UAT channel is at [978] MHz and has a signaling rate of just over 1 Mbps. A, single channel, architecture ensures seamless air-air connectivity and obviates the need for multi-channel receivers or tuning procedures. The UAT channel has been sized to ensure ADS-B performance is maintained in future high traffic density environments. Additionally, the UAT waveform has been designed specifically for maximum tolerance to self-interference and other pulsed interference encountered in the band. Details on the UAT waveform can be found in the UAT RF SARPs. Detailed information on UAT ADS-B performance assessment in projected future high-density traffic environments is provided in Appendix D. This assessment also accounts for all expected sources of interference from other systems. The detailed assumptions, made to account for impairments from this interference environment, are detailed in Appendix D.

There are two basic types of broadcast transmissions - or messages - on the UAT channel: the ADS-B message, and the Ground Uplink message. The ADS-B Message is broadcast by an aircraft. TIS-B information will be broadcast by a ground station and is transmitted using the ADS-B message format. The Ground Uplink message is used by ground stations to uplink FIS data such as text and graphical weather data, advisories, and other aeronautical information, to any aircraft that may be in the service volume of the ground station. Regardless of type, each message has two fundamental components: the message payload that contains user information, and message overhead, principally consisting of forward error correction code parity, that supports the error-free transfer of the data. Details on the format of these message types are provided in Sections 3.1.1 and 3.1.2. Details on the contents and format of the message payloads are provided in Sections 3.2.1 and 3.2.2.

2.3 Timing Structure and Media Access

UAT support for multiple services is accomplished using a hybrid medium access approach that incorporates both time-slotted and random un-slotted access. By virtue of its waveform, signaling rate, precise time reference, and message-starting discipline, UAT can also support independent measurement of range to most other participants in the medium.

UAT Message transmissions are governed by a combination of time-slotted and random-access techniques. Figure 2-2 illustrates the basic UAT Message timing structure called a UAT frame. A frame is one second long and begins at the start of each Universal Coordinated Time (UTC) second. Each frame is divided into two segments: the Ground Segment in which Ground Uplink messages are broadcast in one or more time slots, and the ADS-B Segment in which ADS-B messages are broadcast by aircraft and, TIS-B messages from ground stations. Guard times are incorporated between the segments to allow for signal propagation and timing drift. The UAT frame is further divided into Message Start Opportunities (MSOs) that are spaced at 250μs intervals. This spacing represents the smallest time increment used by UAT for scheduling message transmissions, and all such transmissions must start only at a valid MSO.



Notes:

1. *Shaded segments represent guard times for signal propagation and timing drift (not to scale).*
2. *ADS-B transmissions will partially occur within the final guard interval when the last MSO is selected*

Figure 2-2. UAT Frame

As shown in Figure 2-2, 176 milliseconds in each 1-second UAT frame are devoted to Ground Uplink message transmissions, and 800ms are devoted to ADS-B message transmissions. MSOs start at the end of the initial 6ms guard time, are spaced at 250µs intervals, and are numbered sequentially from 0 through 3951.

2.3.1 ADS-B Message Transmission

As shown in Figure 2-2, the ADS-B Segment of each UAT frame is 800 milliseconds long, and spans 3200 MSOs (i.e., from MSO 752 to MSO 3951). All aircraft-transmitted ADS-B messages (as well as ground-transmitted TIS-B messages) are transmitted in this segment of the frame. Each UAT-equipped aircraft makes exactly one ADS-B message transmission per frame, and makes a pseudo-random selection from among any of the 3200 MSOs in the segment to start transmission of the message. Approximately 6 milliseconds of guard time are appended after the ADS-B Segment to fill out the UAT frame to the end of the UTC second.

The pseudo-random selection of an MSO within each UAT frame for the start of an aircraft's ADS-B message is intended to prevent two aircraft from systematically interfering with each other's ADS-B message transmissions. Adherence to the MSO-based timing scheme enables the receiving UAT equipment to determine range to the UAT equipment that transmitted the message. This information could be used in validity checks of the position data conveyed in the ADS-B message itself. More information on UAT support for an independent ADS-B validation application is presented in Appendix E.

2.3.2 TIS-B Transmission

From the perspective of a receiving aircraft, TIS-B transmissions will appear to be nearly identical to ADS-B messages both in terms of message format and media access. One approach for ground station transmission of TIS-B messages is provided in Appendix A[1].

[1] Other approaches for TIS-B transmission are possible and may be defined in future versions of this manual.

2.3.3 Ground Uplink Message Transmission (FIS-B)

Ground Uplink messages are used to support FIS-B. Ground Uplink messages will occur within one or more of the 32 time slots defined within the ground segment of the UAT frame. Detailed procedures for Ground Uplink message transmission are provided in Appendix A.

2.4 Basic Avionics Operation and Equipage Levels

2.4.1 Avionics Operating Concept

Implementations will consist of transmit and receive subsystems. Most implementations will include both subsystems; however, transmit-only configurations are also possible. Figure 2-3 shows the high level functions of an avionics implementation that supports both transmission and reception.

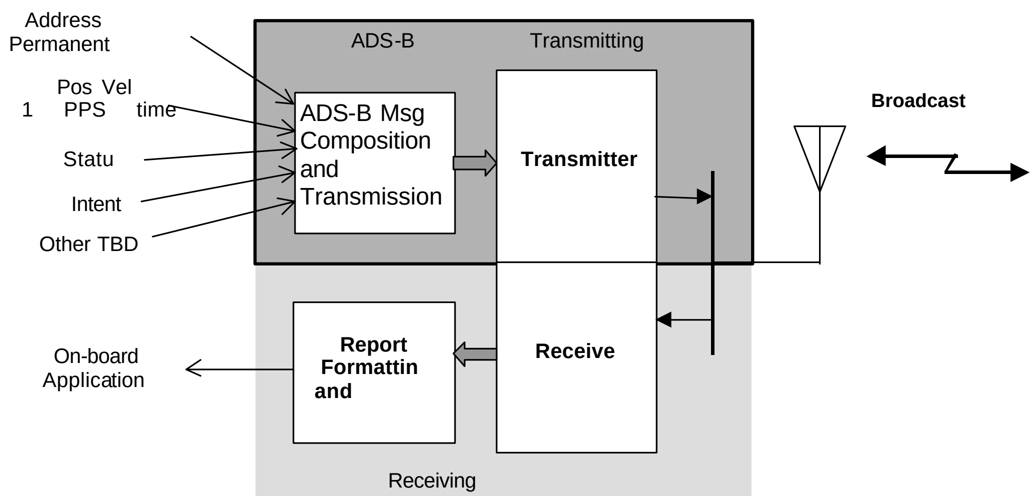


Figure 2-3. High Level Function of UAT Avionics

The transmitting subsystem performs the following basic functions:

- Determine the proper message format based on the predetermined (fixed) message transmit schedule.
- Receive various ADS-B input data and format into the ADS-B message structure.
- Determine time for transmission (once per second) based on pseudorandom seed.
- Select the antenna for transmission (for installations requiring transmit diversity)
- Transmit the message over the UAT channel.

These functions result in one message transmitted each second. Additionally, the transmitting subsystem may make a determination of whether its "Vertical Status" is ON GROUND or AIRBORNE. For some installations, the ADS-B message format may change slightly depending on the Vertical Status Reports. Otherwise, the transmitting subsystem operates in a consistent manner throughout the flight making one ADS-B message transmission each second in a predefined schedule and format.

The receiving subsystem performs the following basic functions:

- Select antenna for reception (if required for the installation)

- Detection and decoding of ADS-B and Ground Uplink messages on the UAT channel.
- Apply "Successful Message Reception" criteria to each detected message to ensure integrity.
- For each Successful Message Reception, format resulting message payload into report format and output report to on-board applications.

Reports are generated in response to messages received (ADS-B or Ground Uplink). The conditions and procedures for generation of reports are straightforward: each message successfully received will trigger the generation of a report. Each report includes the unaltered payload of the message just received. This same procedure applies to both ADS-B and Ground Uplink messages.

2.4.2 Avionics Equipage Classes

ADS-B equipment is categorized into aircraft system equipage classes as defined in RTCA/DO-242A (ADS-B MASPS)[1]. For UAT ADS-B equipment, the installed performance of these equipment classes is defined by Table 2-1.

The ADS-B MASPS "A1" equipment has been divided into two classes, based on the maximum altitude that the aircraft is operated under. For A1 aircraft that always operate below 18,000 feet MSL, the "A1 Low" class is created, and abbreviated throughout this document as "A1L." For A1 aircraft that have no altitude operating restrictions, the "A1 High" class is created, and abbreviated throughout this document as "A1H." The only equipment performance difference between classes A1L and A1H is the Transmitter RF output power, as shown in Table 2-1.

The remainder of the interactive aircraft/vehicle classes (A0, A2, and A3) are as defined in RTCA/DO-242A.

For "B" class aircraft that always operate below 18,000 feet MSL, the "B0" class is created. For "B" class aircraft that have no altitude operating restrictions, the "B1" class is available. The ADS-B MASPS "B0" class (broadcast-only aircraft) is defined as having transmitter characteristics and payload capability identical to the UAT A0 interactive aircraft class. The ADS-B MASPS "B1" class (broadcast-only aircraft) is defined as having transmitter characteristics and payload capability identical to the UAT A1H interactive aircraft class.

The characteristics of the ADS-B MASPS "B2" class (broadcast-only ground vehicle) are defined in Table 2-1.

[1] The concept of equipment classes is introduced here primarily because it is relevant to the performance assessment presented in Appendix D. The RTCA definition for equipment classes is adopted since ICAO requirements for ADS-B are not yet developed at the time of preparation of this manual.

Table 2-1: **UAT Installed Equipment Classes**

Typical Application	Equipage Class	Tx RF Power Delivered to Antenna System	Antenna Diversity Minimum Requirements	
			Tx	**Rx**
Aid to Visual Acquisition	A0	Low Power *(Altitude always below 18,000 feet)*	Single Antenna (see Note 4)	Single Antenna (see Note 4)
Conflict Avoidance	A1L		Alternate	Alternate
	A1H	Medium Power	Alternate	Alternate
Separation and Sequencing	A2	Medium Power	Alternate	Dual Receiver
Deconfliction Planning	A3 (extended range)	High Power	Alternate	Dual Receiver
Tx-Only Airborne Vehicle	B0	Low Power *(Altitude always below 18,000 feet)*	Single Antenna (see Note 4)	n/a
Tx-Only Airborne Vehicle	B1	Medium Power	Alternate	n/a
Surface Vehicle	B2	+28 to +32 dBm	Single Antenna	n/a
Obstacle	B3	+30 dBm (minimum)	Single Antenna	n/a

Notes:

1. See §2.4.2.1 for definition of Transmitter RF power levels.

2. Transmitter RF power requirement depends on the aircraft maximum altitude capability. Low-altitude aircraft (< 18,000 feet max altitude) need not support the higher-power transmitter requirements due to line-of-site limitations.

3. Top antenna is not required if use of a single antenna does not degrade signal propagation. This allows for single antenna installation on radio-transparent airframes.

4. For a single-antenna installation, antenna gain pattern performance should be shown at least equivalent to that of a quarter-wave resonant antenna mounted on the fuselage bottom surface.

2.4.2.1 Transmitting Subsystem

An ADS-B Transmitting Subsystem is classified according to the unit's range capability and the set of parameters it is capable of transmitting. Table 2-2 defines the transmitter power levels. Power levels are measured in terms of power presented to the transmitting antenna.

Table 2-2: Transmitter Power Requirements

Power Classification	Minimum Power at Antenna	Maximum Power at Antenna
Low	7.0 watts (+38.5 dBm)	18 watts (+42.5 dBm)
Medium	16 watts (+42 dBm)	40 watts (+46 dBm)
High	100 watts (+50 dBm)	250 watts (+54 dBm)

Note: These transmitter power requirements are referenced to the power delivered to the antenna, and assume transmit antenna gain of 0 dB. Alternate means that demonstrates equivalent performance can be approved. Refer to Appendix E for guidance.

2.4.2.2 Receiving Subsystem

No distinction in receiver sensitivity by category is made; all receivers have the same sensitivity requirements. The receiver sensitivity is –93 dBm at the receiver antenna for 90% Message Success Rate for Long ADS-B Messages, and –91 dBm at the receiver antenna for 90% Message Success Rate of Ground Uplink (ground-to-air) messages.

2.5 Basic Ground Station Operation

The UAT ground station will operate as an ADS-B sensor identically to that of airborne units. The ground subsystem will also be capable of transmitting Ground Uplink messages in one or more of the 32 assigned Ground Segment time slots. TIS-B uplink from ground station will utilize the ADS-B message format and the ADS-B segment of the UAT frame; the avionics receiving subsystem makes no distinction in its processing of ADS-B and TIS-B data—although the airborne application can distinguish these via the Address Qualifier field. The typical ground station antenna is a 6-8 dBi omni DME-style. Figure 2-4 gives an overview of the ground station.

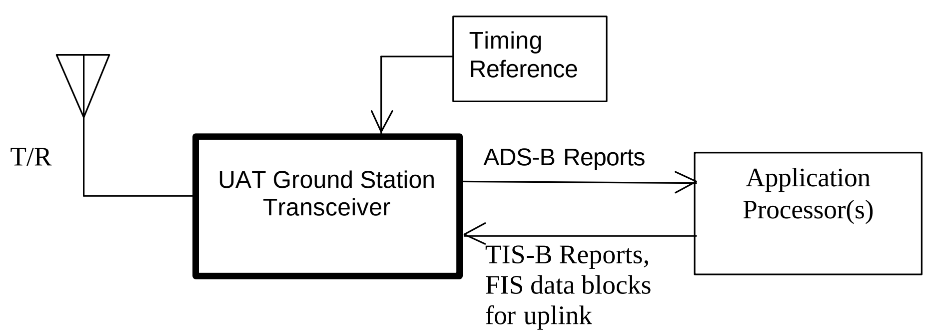


Figure 2-4. UAT Ground Station Block Diagram

A single ground station antenna/transceiver is capable of supporting the following functions:

- ADS-B sensor
- Provides time-of-arrival measurement of ADS-B transmission for independent range to target measurement based on a single sensor. Networked ground stations with overlapping coverage allows surveillance based on the "multilateration" technique wherein a 2-D position is derived completely independent of the ADS-B reported position.
- FIS-B uplink

- TIS-B uplink
- Provides timing beacon to airborne users that can serve as backup timing (see Section 4.1.1) or potentially as backup navigation.

Additional guidance on operation of ground infrastructure including network aspects and interference considerations is provided in Appendix A.

3 Formats

3.1 UAT Message

3.1.1 ADS-B Message Formats

The ADS-B Message format is shown in Figure 2-3. Each message element is described in detail in §3.1.1 through §3.1.1.3.

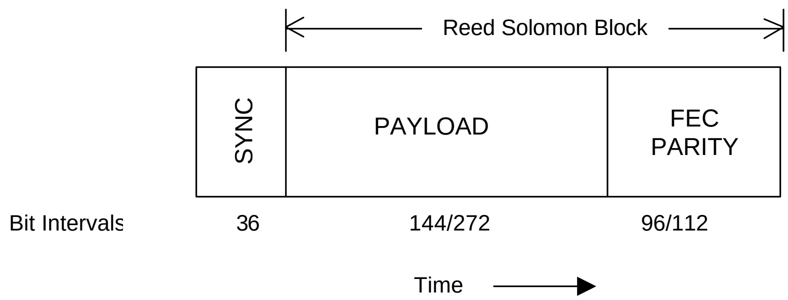


Figure 2-3: ADS-B Message Format

Notes:

1. *All bit intervals depicted in Figure 2-3 comprise the ACTIVE state of the transmitter as defined in UAT MOPS, RTCA DO-282 §2.2.2.5.*

2. *Traffic Information Services-Broadcast (TIS-B) transmissions use the ADS-B Message format — including use of the same synchronization pattern. Other approaches are possible but beyond the scope of this document.*

3.1.1.1 Synchronization

Following ramp up, the message **shall** include a 36-bit synchronization sequence. For the ADS-B Messages the sequence **shall** be:

111010101100110111011010010011100010

with the left-most bit transmitted first.

3.1.1.2 Payload

The format, encoding and transmission order of the payload message element is defined in §3.2.

3.1.1.3 FEC Parity

3.1.1.3.1 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 ADS-B Message: Parity **shall** be per 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 ADS-B Message: Parity **shall** be per 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:

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

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: See Appendix B for more information on the implementation of the Reed Solomon code.

3.1.1.3.2 Generation and Transmission Order of FEC Parity

FEC Parity bytes **shall** be ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte **shall** be most significant to least significant. FEC Parity bytes **shall** follow the message payload.

Note: See Appendix B for a message generation and encoding example.

3.1.2 Ground Uplink Message Formats

The Ground Uplink Message format is shown in Figure 2-4. Each message element is described in detail in §3.1.2.1 through §3.2.

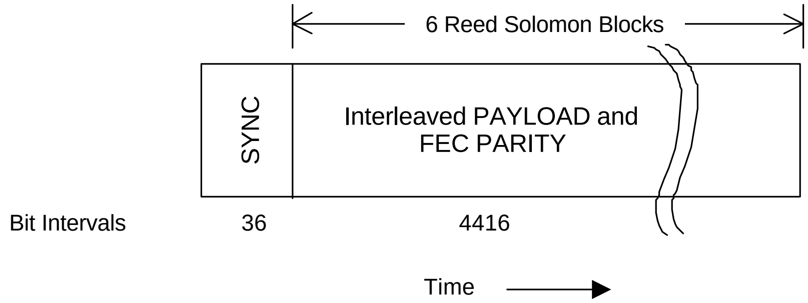


Figure 2-4: Ground Uplink Message Format

3.1.2.1 Synchronization

The polarity of the bits of the synchronization sequence used for Ground Uplink Messages is inverted from that used for the ADS-B Message, that is, the ONEs and ZEROs 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.*

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

3.1.2.2.1 Code Type

The FEC Parity generation is based on a systematic RS 256-ary code with 8 bit code word symbols. FEC Parity generation for each of the six blocks is per RS (92,72) code.

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

The primitive polynomial of the code is as follows:

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

The generator polynomial is as follows:

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

Where P = 139

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

Note: *See Appendix B for more information on Reed Solomon encoding.*

3.1.2.2.2 Generation and 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 payload.

Note: *See Appendix B for a message generation and encoding example. Even though the example is for an ADS-B Message, the procedure applies to any Reed Solomon block being encoded/decoded.*

3.1.2.3 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 2-4 consists of 6 interleaved Reed-Solomon 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 2-6. In Table 2-6, 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 2-6: Ground Uplink Interleaver Matrix

RS Block	Payload Byte # (From §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 Table 2-6, 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.*

3.2 UAT Message Payload

3.2.1 ADS-B Message Payload

3.2.1.1 Payload Type

Each transmitted ADS-B Message contains a payload that the receiver first identifies by the "PAYLOAD TYPE CODE" encoded in the first 5 bits of the payload. The Payload Type Code allows the receiver to interpret the contents of the ADS-B Message payload per the definition contained in §3.2.1.2 through §3.2.1.5.8.

3.2.1.2 Payload Elements

For convenience, the ADS-B Message payload is organized into *payload elements*. These elements contain the individual message *fields* (e.g., LATITUDE, ALTITUDE, etc) that correspond to the various report elements issued by an ADS-B Receiving Subsystem to an application system as defined in the ADS-B MASPS, RTCA Document DO-242A. Payload elements and their lengths are shown in Table 2-7.

Table 2-7: ADS-B Payload Elements

Payload Element	Payload Bytes	Applicable DO-242A Reports	Subparagraph References
HEADER (HDR)	4	All	§3.2.1.5.1
STATE VECTOR (SV)	13	State Vector	§3.2.1.5.2
MODE STATUS (MS)	12	Mode Status	§3.2.1.5.4
AUX. STATE VECTOR (AUX SV)	5	State Vector, Air Reference Velocity	§3.2.1.5.5
TARGET STATE (TS)	5	Target State	§3.2.1.5.6 §3.2.1.5.7
TRAJECTORY CHANGE +0 (TC+0)	12	Trajectory Change	§3.2.1.5.8
TRAJECTORY CHANGE +1 (TC+1)	12	Trajectory Change	§3.2.1.5.8

3.2.1.3 ADS-B Payload Composition by Payload Type Code

Table 2-8 provides the assignment of payload elements to each Payload Type Code.

Table 2-8: Composition of ADS-B Payload

<table>
<tr><th rowspan="2">Payload Type Code</th><th colspan="7">ADS-B Message Payload Byte Number</th></tr>
<tr><th>1 ---- 4</th><th>5 ---- 17</th><th>18 --------- 24</th><th>25 ---- 28</th><th>29</th><th>30 --- 33</th><th>34</th></tr>
<tr><td>0 (Note 1)</td><td>HDR</td><td>SV</td><td>Res</td><td colspan="4">Byte 19-34 Not present in Type 0</td></tr>
<tr><td>1</td><td>HDR</td><td>SV</td><td colspan="3">MS</td><td colspan="2">AUX SV</td></tr>
<tr><td>2</td><td>HDR</td><td>SV</td><td colspan="3">Reserved (Note 2)</td><td colspan="2">AUX SV</td></tr>
<tr><td>3</td><td>HDR</td><td>SV</td><td colspan="3">MS</td><td>TS</td><td>Res</td></tr>
<tr><td>4</td><td>HDR</td><td>SV</td><td colspan="3">Reserved for TC+0 (Note 2)</td><td>TS</td><td>Res</td></tr>
<tr><td>5</td><td>HDR</td><td>SV</td><td colspan="3">Reserved for TC+1 (Note 2)</td><td colspan="2">AUX SV</td></tr>
<tr><td>6</td><td>HDR</td><td>SV</td><td>Res. (Note 2)</td><td>TS</td><td>Res</td><td colspan="2">AUX SV</td></tr>
<tr><td>7</td><td>HDR</td><td>SV</td><td colspan="5" rowspan="4">Reserved (Note 3)</td></tr>
<tr><td>8</td><td>HDR</td><td>SV</td></tr>
<tr><td>9</td><td>HDR</td><td>SV</td></tr>
<tr><td>10</td><td>HDR</td><td>SV</td></tr>
<tr><td>11 through 29</td><td>HDR</td><td colspan="6">Reserved (Note 2)</td></tr>
<tr><td>30, 31</td><td>HDR</td><td colspan="6">Reserved for Developmental Use (Note 4)</td></tr>
</table>

Notes:

1. *Payload Type 0 is conveyed in the Basic ADS-B Message; byte 18 is reserved for future definition.*

2. *Not defined in this MOPS. Reserved for definition in future versions.*

3. *Payload Types 7 – 10 will allow a degree of backward compatibility with future message definition for receivers operating according to this MOPS.*

4. *Payload Types 30 and 31 are intended for developmental use, such as to support on-air flight testing of new payload types, prior to their adoption in future MOPS versions. These payload types should be ignored by MOPS compliant equipment.*

3.2.1.4 Payload Transmission Order

The ADS-B Message payload **shall** be transmitted in byte order with byte #1 first. Within each byte, bits **shall** be transmitted in order with bit #1 transmitted first. Bit-level definition of the payload is provided in §3.2.1.5 through §3.2.1.5.8.

3.2.1.5 Payload Contents

3.2.1.5.1 HEADER Element

Format for the HEADER element is defined in Table 2-9. This encoding **shall** apply to ADS-B Messages with PAYLOAD TYPE CODES of "0" through "31." Each of the fields shown is defined in §3.2.1.5.1.1 through §3.2.1.5.1.3.6.

Table 2-9: Encoding of HEADER Element into ADS-B Payload

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1	(MSB)		Payload Type Code		(LSB)	Address Qualifier		
2	(MSB)A1	A2	A3	. . .				
3				Address				
4					. . .	A22	A23	A24(LSB)

.

.

3.2.1.5.1.1 "PAYLOAD TYPE CODE" Field Encoding

The "PAYLOAD TYPE CODE" field is a 5-bit (bit 1 of byte 1 through bit 5 of byte 1) field used to identify the payload for decoding by the receiver. Definition of the "PAYLOAD TYPE CODE" field encoding that **shall** be used for all ADS-B Messages is provided in Table 2-8.

3.2.1.5.1.2 "ADDRESS QUALIFIER" Field Encoding

The "ADDRESS QUALIFIER" field is a 3-bit (bit 6 of byte 1 through bit 8 of byte 1) field used to indicate what the 24-bit "ADDRESS" field represents. Definition of the "ADDRESS QUALIFIER" field encoding that **shall** be used for all ADS-B Messages is provided in Table 2-10. The Address Selection Input (ICAO versus Temporary) is used to determine whether to transmit using the ICAO Address or a self-assigned Temporary Address.

If the Address Selection Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "ADDRESS QUALIFIER" **shall** default to a value of ALL ZEROs.

Table 2-10: "ADDRESS QUALIFIER" Encoding

Address Qualifier (binary)			Address Qualifier (decimal)	Address Type	Reference subparagraph
Bit 6	Bit 7	Bit 8			
0	0	0	0	ADS-B target with ICAO 24-bit address	3.2.1.5.1.3.1
0	0	1	1	ADS-B target with self-assigned temporary address	3.2.1.5.1.3.2
0	1	0	2	TIS-B target with ICAO 24-bit address	3.2.1.5.1.3.3
0	1	1	3	TIS-B target with track file identifier	3.2.1.5.1.3.4
1	0	0	4	Surface Vehicle	3.2.1.5.1.3.5
1	0	1	5	Fixed ADS-B Beacon	3.2.1.5.1.3.6
1	1	0	6	(Reserved)	
1	1	1	7	(Reserved)	

3.2.1.5.1.3 "ADDRESS" Field Encoding

The "ADDRESS" field is a 24-bit (bit 1 of byte 2 through bit 8 of byte 4) field used in conjunction with the "ADDRESS QUALIFIER" field to identify the participant. The meaning of the "ADDRESS" field depends on the "ADDRESS QUALIFIER" field as described in §3.2.1.5.1.3.1 through §3.2.1.5.1.3.6.

3.2.1.5.1.3.1 ICAO 24-Bit Aircraft Address of Transmitting Aircraft

An "ADDRESS QUALIFIER" value of ZERO (binary 000) **shall** indicate that the message is an ADS-B Message from an aircraft, and that the "ADDRESS" field holds the ICAO 24-bit address that has been assigned to that particular aircraft. The ICAO Aircraft Address **shall** be stored (or "latched") in the UAT Transmitting System upon Power Up.

If the Address Selection Input is set to the "ICAO," then the ADS-B Transmitting Subsystem **shall** declare a device failure in the event that it's own ICAO 24-bit Address (i.e., the Mode-S Address) is invalid, unavailable, or set to all "ZEROs" or all "ONEs."

Note: *The world-wide method for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9].*

3.2.1.5.1.3.2 Self-Assigned Temporary Address of Transmitting Aircraft

An "ADDRESS QUALIFIER" value of ONE (binary 001) **shall** indicate that the message is an ADS-B Message from an aircraft, and that the "ADDRESS" field holds the transmitting aircraft's self-assigned ownship temporary address.

The self-assigned temporary address **shall** be generated as follows:

Let: $ADDR_P$ = the ICAO 24-bit address that has been assigned to the aircraft;

$ADDR_T$ = the temporary address that is to be generated;

M(1) = the 12 least significant bits (LSBs) of the ownship "LATITUDE" field (per §3.2.1.5.2.1) at the time the temporary address option is selected;

M(2) = the 12 least significant bits (LSBs) of the ownship "LONGITUDE" field (per §3.2.1.5.2.1) at the time the temporary address option is selected;

M(3) = $4096 \times M(1) + M(2)$; and

TIME = the number of seconds that have elapsed since UTC midnight at the time the temporary address option is selected, represented as a 24-bit number.

Also, let "⊕" denote the modulo 2 bit-by-bit addition (or "exclusive OR") operation.

a. If the transmitting aircraft's ICAO 24-bit address $ADDR_P$ is available, then the temporary address $ADDR_T$ **shall** be the modulo 2, bit-by-bit summation of the permanent address and M(3), that is:

$$ADDR_T = ADDR_P \oplus M(3).$$

b. If the aircraft's 24-bit ICAO address $ADDR_P$ is <u>not</u> available, then time of day **shall** be used as an additional randomizer. In that case, the temporary address $ADDR_T$ **shall** be the modulo 2, bit-by-bit summation of TIME and M(3), that is,

$$ADDR_T = TIME \oplus M(3).$$

Note: *Analysis indicates that the probability of two aircraft in the same operational area having identical* $ADDR_T$ *values should be well below the observed probability of having duplicate ICAO 24-bit addresses owing to installation errors.*

3.2.1.5.1.3.3 ICAO 24-Bit Aircraft Address of TIS-B Target Aircraft

An "ADDRESS QUALIFIER" value of TWO (binary 010) is used to indicate that the message is for a TIS-B target and the "ADDRESS" field holds the ICAO 24-bit address that has been assigned to the target aircraft being described in the message.

Note: *The world-wide scheme for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9].*

3.2.1.5.1.3.4 TIS-B Track File Identifier

An "ADDRESS QUALIFIER" value THREE (binary 011) is used to indicate that the message is for a TIS-B target and that the "ADDRESS" field holds a TIS-B track file identifier by which the TIS-B data source identifies the target aircraft being described in the message.

Note: *It is beyond the scope of this MOPS to specify the method by which a TIS-B service provider would assign track file identifiers for those TIS-B targets for which the ICAO 24-bit address is unknown.*

3.2.1.5.1.3.5 Surface Vehicle Address

An "ADDRESS QUALIFIER" value of FOUR (binary 100) is used to indicate that the "ADDRESS" field holds the address of a surface vehicle authorized to operate in the airport's surface movement area.

Note: *It is beyond the scope of this MOPS to specify the method by which ADS-B surface vehicle addresses are assigned.*

3.2.1.5.1.3.6 Fixed ADS-B Beacon Address

An "ADDRESS QUALIFIER" value of FIVE (binary 101) is used to indicate that the "ADDRESS" field holds the address assigned to a fixed ADS-B beacon or "parrot."

Note: *It is beyond the scope of this MOPS to specify the method by which ADS-B beacon addresses are assigned.*

3.2.1.5.2 STATE VECTOR Element

Format for the STATE VECTOR element is defined in Table 2-11. This encoding **shall** apply to ADS-B Messages with PAYLOAD TYPE CODES of "0" through "10," when the ADDRESS QUALIFIER value is "0," "1," "4" or "5." Each of the fields shown is defined in §3.2.1.5.2.1 through §3.2.1.5.2.10.

Table 2-11: Format of STATE VECTOR Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
.								
5	(MSB)							
6				Latitude (WGS-84)				
7							(LSB)	(MSB)
8								
9				Longitude (WGS-84)				
10							(LSB)	Alt Type
11	(MSB)			Altitude				
12				(LSB)	(MSB)	NIC		(LSB)
13	(MSB) A/G State (LSB)		Reserved					
14				Horizontal Velocity				
15								
16		Vertical Velocity or Aircraft Length/Width Code						
17					UTC	Reserved		
.								
.								

3.2.1.5.2.1 "LATITUDE" and "LONGITUDE" Field Encoding

a. The "LATITUDE" field is a 23-bit (bit 1 of byte 5 through bit 7 of byte 7) field used to encode the latitude of the ADS-B Transmitting Subsystem in WGS-84. The encoding of this field **shall** be as indicated in Table 2-12. Also see Figure 2-5.

b. The "LONGITUDE" field is a 24-bit (bit 8 of byte 7 through bit 7 of byte 10) field used to encode the latitude of the ADS-B Transmitting Subsystem in WGS-84. The encoding of this field **shall** be as indicated in Table 2-12. Also see Figure 2-5.

c. The encoding of ALL ZEROs in the "LATITUDE" <u>and</u> "LONGITUDE" <u>and</u> "NIC" (§3.2.1.5.2.4) fields **shall** indicate that Latitude/Longitude information is "unavailable."

Note: *Since the encoding of ALL ZEROs is a valid location on the earth, ADS-B Receiving Subsystems will interpret this as Latitude/Longitude information "unavailable" only if the NIC field is also set to ZERO.*

If either the Latitude Input or the Longitude Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the LATITUDE, LONGITUDE and NIC fields **shall** default to a value of ALL ZEROs.

<u>Table 2-12:</u> Angular Weighted Binary Encoding of Latitude and Longitude

Quadrant	"LATITUDE" or "LONGITUDE" bits	Meaning $LSB = \frac{360}{2^{24}} = 0.00002146°$	
	MSB LSB	**Latitude**	**Longitude**
	0000 0000 0000 0000 0000 0000	ZERO degrees (Equator)	ZERO degrees (Prime Meridian)
1st	0000 0000 0000 0000 0000 0001	*LSB* degrees North	*LSB* degrees East
quadrant	…	…	…
	0011 1111 1111 1111 1111 1111	(90-*LSB*) degrees North	(90-*LSB*) degrees East
	0100 0000 0000 0000 0000 0000	90 degrees (North Pole)	90 degrees East
2nd	0100 0000 0000 0000 0000 0001	<Illegal Values>	(90+*LSB*) degrees East
quadrant	…	<Illegal Values>	…
	0111 1111 1111 1111 1111 1111	<Illegal Value>	(180-*LSB*) degrees East
	1000 0000 0000 0000 0000 0000	<Illegal Value>	180 degrees East or West
3rd	1000 0000 0000 0000 0000 0001	<Illegal Value>	(180-*LSB*) degrees West
quadrant	…	<Illegal Values>	…
	1011 1111 1111 1111 1111 1111	<Illegal Values>	(90-LSB) degrees West
	1100 0000 0000 0000 0000 0000	-90 degrees (South Pole)	90 degrees West
4th	1100 0000 0000 0000 0000 0001	(90-*LSB*) degrees South	(90-*LSB*) degrees West
quadrant	…	…	…
	1111 1111 1111 1111 1111 1111	*LSB* degrees South	*LSB* degrees West

<u>Notes</u>:

1. *The most significant bit (MSB) of the angular weighted binary "LATITUDE" is omitted from the transmitted message. This is because all valid Latitudes, other than the Latitude of the North pole (exactly 90 degrees North), have the same value in their 2 most significant bits. The application using the ADS-B reports has the responsibility to differentiate the North and South Poles.*

2. *Raw data used to establish the Latitude or Longitude fields will normally have more resolution (i.e., more bits) than that required by the Latitude or Longitude fields. When converting such data to the Latitude or Longitude subfields, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the Latitude or Longitude field.*

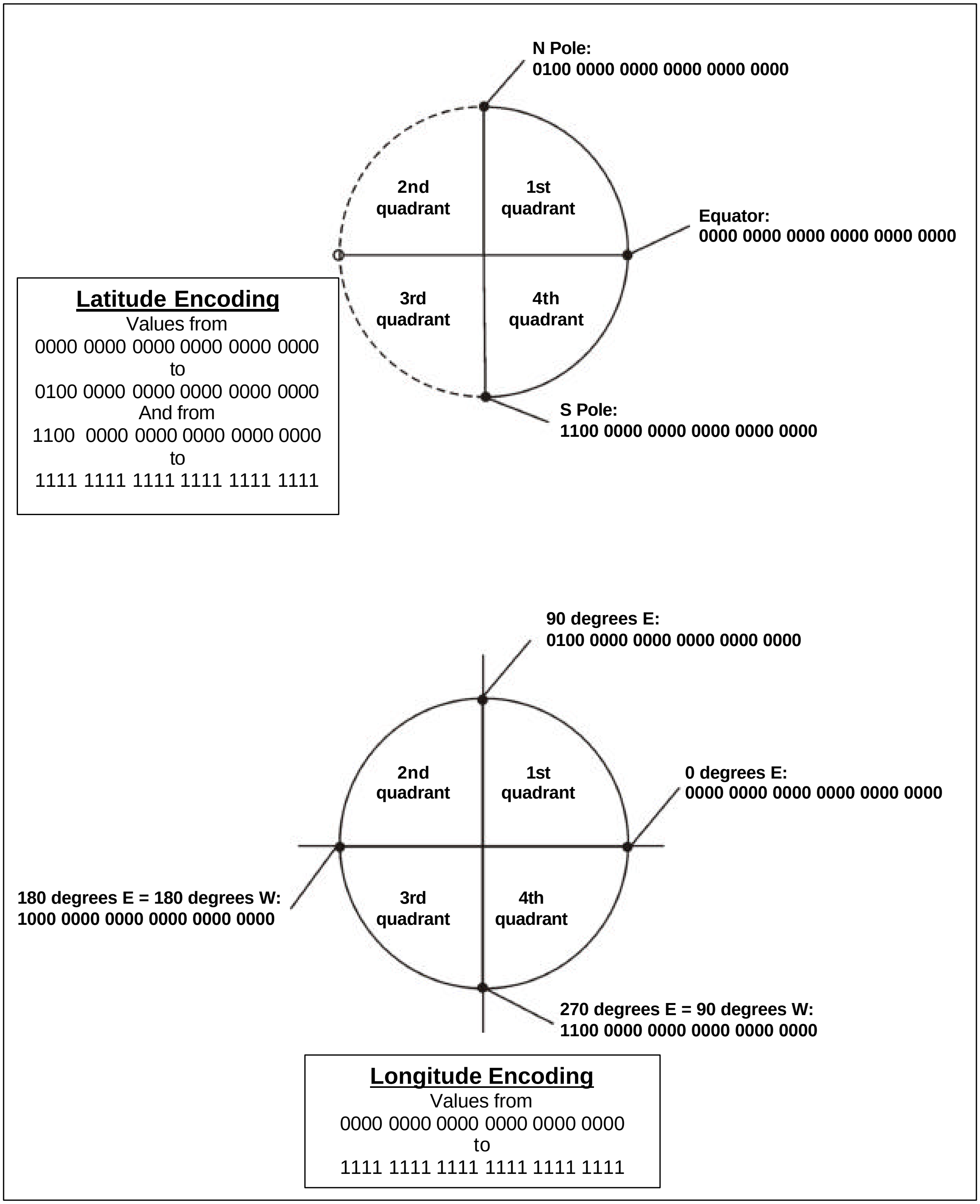


Figure 2-5: Angular Weighted Binary Encoding of Latitude and Longitude

3.2.1.5.2.2 "ALTITUDE TYPE" Field Encoding

The "ALTITUDE TYPE" field is a 1-bit (bit 8 of byte 10) field used to identify the source of information in the "ALTITUDE" field. The encoding of this field is reflected in Table 2-13.

If the Altitude Type Selection Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "ALTITUDE TYPE" **shall** default to a value of ZERO if Pressure Altitude is available.

Table 2-13: "ALTITUDE TYPE" Encoding

Altitude Type	**"ALTITUDE" Field** (§3.2.1.5.2.3)	**"SECONDARY ALTITUDE" Field** (§3.2.1.5.5.1)
0	Pressure Altitude	Geometric Altitude
1	Geometric Altitude	Pressure Altitude

Note: *"Pressure Altitude" refers to "Barometric Pressure Altitude" relative to a standard atmosphere at a standard pressure of 1013.2 millibars (29.92 in Hg) and specifically **DOES NOT** refer to "Barometric Corrected Altitude."*

A means **shall** be provided to operationally inhibit the broadcast of Pressure Altitude information, making it unavailable for transmission. A means **shall** be provided to operationally select the preferred ALTITUDE TYPE that is reported if more than one ALTITUDE TYPE is available. If only one ALTITUDE TYPE is available, then that Altitude **shall** be indicated in the "ALTITUDE TYPE" field.

Note: *The means to operationally inhibit the broadcast of pressure altitude information can be used at the request of ATC, or when altitude is determined to be invalid by the pilot. This is similar to the means defined in 14 CFR, §91.217(a).*

If the Altitude Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then that Altitude **shall** be deemed unavailable for the purposes of encoding the "ALTITUDE TYPE" field.

3.2.1.5.2.3 "ALTITUDE" Field Encoding

The "ALTITUDE" field is a 12-bit (bit 1 of byte 11 through bit 4 of byte 12) field used to encode the altitude of the ADS-B Transmitting Subsystem. The encoding of this field **shall** be as indicated in Table 2-14.

Table 2-14: "ALTITUDE" Encoding

Coding (binary) MSB LSB	**Coding** (decimal)	**Meaning**
0000 0000 0000	0	Altitude information unavailable
0000 0000 0001	1	Altitude = -1000 feet
0000 0000 0010	2	Altitude = -975 feet
…	…	…
0000 0010 1000	40	Altitude = -25 feet
0000 0010 1001	41	Altitude = ZERO feet
0000 0010 1010	42	Altitude = 25 feet
…	…	…
1111 1111 1110	4094	Altitude = 101,325 feet
1111 1111 1111	4095	Altitude > 101,337.5 feet

Note: *Raw data used to establish the "ALTITUDE" field will normally have more resolution (i.e., more bits) than that required by the "ALTITUDE" field. When converting such data to the "ALTITUDE" field, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "ALTITUDE" field.*

3.2.1.5.2.4 "NIC" Field Encoding

The Navigation Integrity Category ("NIC") field is a 4-bit (bits 5 through 8 of byte 12) field used to allow surveillance applications to determine whether the reported position has an acceptable level of integrity for the intended use. The value of the NIC parameter specifies an integrity containment radius, R_C. The encoding of this field **shall** be as indicated in Table 2-15.

If the NIC Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "NIC" **shall** default to a value of ALL ZEROs.

Table 2-15: "NIC" Encoding

NIC binary MSB … LSB	**NIC (decimal)**	**Horizontal and Vertical Containment Bounds**	**Comment**
0000	0	$R_C \geq$ 37.04 km (20 NM)	Unknown Integrity
0001	1	$R_C <$ 37.04 km (20 NM)	RNP-10 containment radius
0010	2	$R_C <$ 14.816 km (8 NM)	RNP-4 containment radius
0011	3	$R_C <$ 7.408 km (4 NM)	RNP-2 containment radius
0100	4	$R_C <$ 3.704 km (2 NM)	RNP-1 containment radius
0101	5	$R_C <$ 1852 m (1 NM)	RNP-0.5 containment radius
0110	6	$R_C <$ 1111.2 m (0.6 NM)	RNP-0.3 containment radius
0111	7	$R_C <$ 370.4 m (0.2 NM)	RNP-0.1 containment radius
1000	8	$R_C <$ 185.2 m (0.1 NM)	RNP-0.05 containment radius
1001	9	$R_C <$ 75 m and VPL < 112 m	e.g., WAAS HPL, VPL
1010	10	$R_C <$ 25 m and VPL < 37.5 m	e.g., WAAS HPL, VPL
1011	11	$R_C <$ 7.5 m and VPL < 11 m	e.g., LAAS HPL, VPL
1100	12	(Reserved)	(Reserved)
1101	13	(Reserved)	(Reserved)
1110	14	(Reserved)	(Reserved)
1111	15	(Reserved)	(Reserved)

Note: *The "NIC" field is closely associated with the "SIL" field (defined in §3.2.1.5.4.6). The value of the "SIL" field is the probability of the true position lying outside the containment radius, R_C, without alerting, including the effects of airborne equipment condition, which airborne equipment is in use, and which external signals are used.*

3.2.1.5.2.5 "A/G STATE" Field Encoding

The Air/Ground State ("A/G STATE") field is a 2-bit (bits 1 and 2 of byte 13) field that indicates the format used for representing horizontal velocity. The value of this field determines the encoding of the "HORIZONTAL VELOCITY" field. The "A/G STATE" field is composed of two (2) 1-bit fields used as follows:

1. The Vertical Status bit (bit 1 of byte 13) is used to reflect the AIRBORNE or ON-GROUND condition as determined in §3.2.1.5.2.5.1.

2. The Subsonic/Supersonic bit (bit 2 of byte 13) is used to indicate the scale factor for the velocity information. The Subsonic/Supersonic bit (bit 2 of byte 13) **shall** be set to ONE (1) if either the East – West velocity OR the North – South velocity, exceeds 1022 knots. The Subsonic/Supersonic bit (bit 2 of byte 13) **shall** be reset to ZERO (0) if the East - West and the North - South velocities, drop below 1000 knots.

The encoding of "A/G STATE" field **shall** be as indicated in Table 2-16.

Table 2-16: "A/G STATE" Field Encoding

Ownship Conditions	"A/G STATE" Field Encoding			**Resulting "HORIZONTAL VELOCITY" Subfield Formats**	
	MSB	LSB			
	Vertical Status (bit 1 of byte 13)	Subsonic/Supersonic (bit 2 of byte 13)	(decimal)	"North Velocity **or** Ground Speed" Subfield Meaning	"East Velocity **or** Track Angle/Heading" Subfield Meaning
AIRBORNE condition. Subsonic condition.	0	0	0	North Velocity (LSB = 1 kt)	East Velocity (LSB = 1 kt)
AIRBORNE condition. Supersonic condition.	0	1	1	North Velocity (LSB = 4 kts)	East Velocity (LSB = 4 kts)
ON GROUND condition.	1	0	2	Ground Speed (LSB = 1 kt)	Track/Heading
<Reserved for TIS-B Uplink Messages>	1	1	3		

3.2.1.5.2.5.1 Determination of Vertical Status

The ADS-B Transmitting Subsystem **shall** determine its Vertical Status (i.e., AIRBORNE or ON-GROUND condition) using the procedure below.

a. If there is a means to automatically determine the Vertical Status of the ADS-B emitter target category, then such information **shall** be used to determine the Vertical Status.

Note: *An "automatic" means of determining vertical status could come from a weight-on-wheels or strut switch, etc. Landing gear deployment is not considered a suitable automatic means.*

b. If there is no means to automatically determine the Vertical Status of the ADS-B Transmitting Subsystem, or the automatic means becomes unavailable after the data timeout value listed in Table 2-64, then the ADS-B Transmitting Subsystem **shall** assume the AIRBORNE condition except under the conditions given for each of the ADS-B Emitter Category types given in Table 2-17. If the conditions given in Table 2-17 are met for the given ADS-B Emitter Category, then the ADS-B Transmitting Subsystem **shall** be in the ON-GROUND condition.

Table 2-17: Determination of ON-GROUND Condition when there is no means to automatically determine Vertical Status

Emitter Category	**Ground Speed**		**Airspeed** (if available)		**Radio Altitude** (if available)
No aircraft type information	Always declare AIRBORNE condition				
Light (ICAO) < 15,500 lbs	Always declare AIRBORNE condition				
Small – 15,500 to 75,000 lbs	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Large – 75,000 to 300,000 lbs	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
High Vortex Large (e.g., B757)	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Heavy (ICAO) - > 300,000 lbs	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Highly Maneuverable > 5G acceleration and high speed	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Rotocraft	Always declare AIRBORNE condition (See Note 1)				
Glider/sailplane	Always declare AIRBORNE condition				
Lighter than air	Always declare AIRBORNE condition (See Note 2)				
Parachutist/sky diver	Always declare AIRBORNE condition				
Ultra light/hang glider/paraglider	Always declare AIRBORNE condition				
Unmanned aerial vehicle	Always declare AIRBORNE condition				
Space/trans-atmospheric vehicle	< 100 knots	***or***	< 100 knots	***or***	< 100 feet
Surface vehicle—emergency vehicle	Always declare ON-GROUND condition				
Surface vehicle—service vehicle	Always declare ON-GROUND condition				
Point Obstacle (includes tethered balloons)	See note 3				
Cluster Obstacle					
Line Obstacle					

Notes:

1. *Because of the unique operating capabilities of rotorcraft, i.e., hover, etc., an operational rotorcraft will always report the AIRBORNE condition unless the ON-GROUND condition is specifically declared in compliance with subparagraph "a." above.*

2. *Because of the unique operating capabilities of "Lighter-than-Air" vehicles, e.g., balloons, an operational "Lighter-than-Air" vehicle will always report the*

AIRBORNE condition unless the ON-GROUND condition is specifically declared in compliance with subparagraph "a." above.

3. *The Vertical Status reported will be appropriate to the situation. In any case the altitude is always present in the transmitted message.*

If any of the inputs used to derive the ON-GROUND condition as specified in Table 2-17 are "unavailable" for the "Data Lifetime" timeout duration listed in Table 2-64, then the input **shall** no longer be used for the purposes of determining the ON-GROUND condition.

3.2.1.5.2.5.2 Validation of Vertical Status

When an automatic means of determining Vertical Status indicates ON-GROUND, the Vertical Status **shall** be changed to AIRBORNE under the conditions listed in Table 2-18.

If any of the inputs used to derive the override of the ON-GROUND condition as specified in Table 2-18 are "unavailable" for the "Data Lifetime" timeout duration listed in Table 2-64, then the input **shall** no longer be used for the purposes of overriding the ON-GROUND condition.

Note: *The Vertical Status can be used by ADS-B Transmitting Subsystems to select only the TOP antenna when in the ON-GROUND condition. A false indication of the automatic means could therefore impact signal availability. To minimize this possibility, this validation procedure has been established.*

Table 2-18: Criteria for Overriding an ON-GROUND Condition Determined by Automatic Means

Emitter Category	**Ground Speed**		**Airspeed** (if available)		**Radio Altitude** (if available)
No aircraft type information	No Change to condition				
Light (ICAO) < 15 500 lbs	No Change to condition				
Small - 15 500 to 75 000 lbs	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Large - 75 000 to 300 000 lbs	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
High Vortex Large (e.g., B757)	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Heavy (ICAO) - > 300 000 lbs	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Highly Maneuverable > 5G acceleration and high speed	> 100 knots	***or***	> 100 knots	***or***	> 50 feet
Rotocraft	No Change to condition				

3.2.1.5.2.6 "HORIZONTAL VELOCITY" Subfields

The "HORIZONTAL VELOCITY" Field is composed of two components:

a. The "North Velocity or Ground Speed" component is represented by an 11-bit subfield from bit 4 of byte 13 through bit 6 of byte 14.

b. The "East Velocity or Track/Heading" component is an 11-bit subfield from bit 7 of byte 14 through bit 1 of byte 16.

Each component can assume multiple formats depending on the "A/G STATE" field. Subparagraphs §3.2.1.5.2.6.1 through §3.2.1.5.2.6.4 describe the encoding for each form of each component.

3.2.1.5.2.6.1 Encoding as "North Velocity" Form

When the "A/G STATE" field is set to "0," or "1," the "North Velocity or Ground Speed" component **shall** assume the "North Velocity" format indicated in Table 2-19.

Table 2-19: "North Velocity" Format

Byte 13					Byte 14					
Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6
N/S Sign	(MSB)				**--North Velocity Magnitude--**					(LSB)

a. The "N/S Sign" subfield (bit 4 of byte 13) **shall** be used to indicate the direction of the North/South velocity vector as shown in Table 2-20.

Table 2-20: "North/South Sign" Encoding

Coding	Meaning
0	NORTH
1	SOUTH

b. The "North Velocity Magnitude" subfield is a 10-bit (bit 5 of byte 13 through bit 6 of byte 14) subfield that **shall** be used to report the magnitude of the North/South velocity of the ADS-B Transmitting Subsystem. The Range, Resolution and No Data encoding of the "North Velocity Magnitude" subfield **shall** be as shown in Table 2-21.

Table 2-21: "North Velocity Magnitude" Encoding

Coding MSB(binary)LSB	**Coding** (decimal)	**Meaning (Subsonic Scale)** (A/G STATE = 0)	**Meaning (Supersonic Scale)** (A/G STATE = 1)
00 0000 0000	0	N/S Velocity not available	N/S Velocity not available
00 0000 0001	1	N/S Velocity is ZERO	N/S Velocity is ZERO
00 0000 0010	2	N/S Velocity = 1 knots	N/S Velocity = 4 knots
00 0000 0011	3	N/S Velocity = 2 knots	N/S Velocity = 8 knots
…	…	…	…
11 1111 1110	1022	N/S Velocity = 1021 knots	N/S Velocity = 4,084 knots
11 1111 1111	1023	N/S Velocity > 1021.5 knots	N/S Velocity > 4,086 knots

Notes:

1. *The encoding represents Positive Magnitude data only. Direction is given completely by the N/S Sign Bit.*

2. *Raw data used to establish the "North Velocity Magnitude" subfield will normally have more resolution (i.e., more bits) than that required by the "North Velocity Magnitude" subfield. When converting such data to the "North Velocity Magnitude*

subfield," the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "North Velocity Magnitude" subfield.

If the North Velocity Magnitude Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "North Velocity Magnitude" subfield **shall** default to a value of ALL ZEROs.

3.2.1.5.2.6.2 Encoding as "Ground Speed" Form

When the "A/G STATE" field is set to "2," the "North Velocity or Ground Speed" component **shall** assume the "Ground Speed" format indicated in Table 2-22.

Table 2-22: "Ground Speed" Format

Byte 13					Byte 14					
Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6
Reserved	(MSB)				**--Ground Speed--**					(LSB)

a. The 1-bit subfield (bit 4 of byte 13) **shall** be "Reserved" and set to ZERO (0).

b. The "Ground Speed" subfield is a 10-bit (bit 5 of byte 13 through bit 6 of byte 14) subfield that **shall** be used to report the Ground Speed of the ADS-B Transmitting Subsystem (in knots). The Range, Resolution and No Data encoding of the "Ground Speed" subfield **shall** be as shown in Table 2-23.

Table 2-23: "Ground Speed" Encoding

Coding MSB(binary)LSB	**Coding** (decimal)	**Meaning (A/G STATE = 2)**
00 0000 0000	0	Ground Speed information not available
00 0000 0001	1	Ground Speed is ZERO
00 0000 0010	2	Ground Speed = 1 knots
00 0000 0011	3	Ground Speed = 2 knots
…	…	…
11 1111 1110	1022	Ground Speed = 1021 knots
11 1111 1111	1023	Ground Speed > 1021.5 knots

Note: *Raw data used to establish the "Ground Speed" subfield will normally have more resolution (i.e., more bits) than that required by the "Ground Speed" subfield. When converting such data to the "Ground Speed" subfield, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "Ground Speed" subfield.*

If the Ground Speed Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "Ground Speed" subfield **shall** default to a value of ALL ZEROs.

3.2.1.5.2.6.3 Encoding as "East Velocity" Form

When the "A/G STATE" field is set to "0" or "1," the "East Velocity or Track Angle/Heading" component **shall** assume the "East Velocity" format indicated in Table 2-24.

Table 2-24: "East Velocity" Format

Byte 14		Byte 15								Byte 16
Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1
E/W Sign	(MSB)				**--East Velocity Magnitude--**					(LSB)

a. The "E/W Sign" subfield (bit 7 of byte 14) **shall** be used to indicate the direction of the East/West velocity vector as shown in Table 2-25.

Table 2-25: "East/West Sign" Encoding

Coding	Meaning
0	EAST
1	WEST

b. The "East Velocity Magnitude" subfield is a 10-bit (bit 8 of byte 14 through bit 1 of byte 16) subfield that **shall** be used to report the East/West velocity of the ADS-B Transmitting Subsystem (in knots). The Range, Resolution and No Data encoding of the "East Velocity Magnitude" subfield **shall** be as shown in Table 2-26.

Table 2-26: "East Velocity Magnitude" Encoding

Coding MSB(binary)LSB	**Coding** (decimal)	**Meaning (Subsonic Scale) (A/G STATE = 0)**	**Meaning (Supersonic Scale) (A/G STATE = 1)**
00 0000 0000	0	E/W Velocity not available	E/W Velocity not available
00 0000 0001	1	E/W Velocity is ZERO	E/W Velocity is ZERO
00 0000 0010	2	E/W Velocity = 1 knots	E/W Velocity = 4 knots
00 0000 0011	3	E/W Velocity = 2 knots	E/W Velocity = 8 knots
…	…	…	…
11 1111 1110	1022	E/W Velocity = 1021 knots	E/W Velocity = 4,084 knots
11 1111 1111	1023	E/W Velocity > 1021.5 knots	E/W Velocity > 4,086 knots

Notes:

1. *The encoding represents Positive Magnitude data only. Direction is given completely by the E/W Sign Bit.*

2. *Raw data used to establish the "East Velocity Magnitude" subfield will normally have more resolution (i.e., more bits) than that required by the "East Velocity Magnitude" subfield. When converting such data to the "East Velocity Magnitude" subfield, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "East Velocity Magnitude" subfield.*

If the East Velocity Magnitude Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "East Velocity Magnitude" subfield **shall** default to a value of ALL ZEROs.

3.2.1.5.2.6.4 Encoding as "Track Angle/Heading" Form

When the "A/G STATE" field is set to "2" the "East Velocity or Track Angle/Heading" component **shall** assume the "Track Angle/Heading" format indicated in Table 2-27. Heading **shall** be encoded if available; if not available Track Angle **shall** be encoded.

Table 2-27: "Track Angle/Heading" Format

Byte 14		Byte 15								Byte 16
Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1
TA/H Type		(MSB)				**--Track Angle/Heading--**				(LSB)

a. The Track Angle/Heading Type ("TA/H Type") is a 2-bit subfield (bit 7 and 8 of byte 14) that **shall** be used to distinguish Track Angle from Heading as shown in Table 2-28.

Table 2-28: "Track Angle/Heading Type" Encoding

Coding	Meaning
00	Data Not Available
01	True Track Angle
10	Magnetic Heading
11	True Heading

b. The "Track Angle/Heading" subfield is a 9-bit (bit 1 of byte 15 through bit 1 of byte 16) subfield that **shall** be used to report the Track Angle or Heading of the ADS-B Transmitting Subsystem as shown in Table 2-29.

Table 2-29: "Track Angle/Heading" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	**Coding** (decimal)	**Meaning**
0 0000 0000	0	Track Angle/Heading is ZERO
0 0000 0001	1	Track Angle/Heading = 0.703125 degrees
0 0000 0010	2	Track Angle/Heading = 1.406250 degrees
0 0000 0011	3	Track Angle/Heading = 2.109375 degrees
…	**…**	**…**
1 1111 1110	510	Track Angle/Heading = 358.593750 degrees
1 1111 1111	511	Track Angle/Heading = 359.296875 degrees

Note: *Raw data used to establish the "Track Angle/Heading" subfield will normally have more resolution (i.e., more bits) than that required by the "Track Angle/Heading" subfield. When converting such data to the "Track Angle/Heading" subfield, the accuracy of the data shall be maintained such that* *it is not worse than +/- ½ LSB where the LSB is that of the "Track Angle/Heading" subfield.*

If either the Track Angle/Heading Type or the Track Angle/Heading Inputs are "unavailable" for the "Data Lifetime" value listed for these inputs in Table 2-64, then the "Track Angle/Heading Type" and the "Track Angle/Heading" subfields **shall** default to values of ALL ZEROs.

3.2.1.5.2.7 "VERTICAL VELOCITY or A/V SIZE" Field

3.2.1.5.2.7.1 Encoding as "Vertical Velocity" Form

When the ADS-B Transmitting Subsystem is in the AIRBORNE condition, the format for the "VERTICAL VELOCITY OR A/V SIZE" field **shall** assume the "Vertical Velocity" form as shown in Table 2-30.

Table 2-30: "Vertical Velocity" Format

Byte 16							Byte 17			
Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4
VV Src	**VV Sign**	(MSB) **--Vertical Rate--** (LSB)								

3.2.1.5.2.7.1.1 "VV Src" Subfield Encoding

The Vertical Velocity Source ("VV Src") subfield is a 1-bit (bit 2 of byte 16) field that **shall** be used to indicate the source of Vertical Rate information as defined in Table 2-31.

Table 2-31: "Vertical Velocity Source" Encoding

Coding	Meaning
0	Vertical Rate information from Geometric Source (GNSS or INS)
1	Vertical Rate information from Barometric Source

Vertical rate information **shall** come from a Geometric source when the *Precision* condition is met, specifically when:

a. The "NAC_P" value is "10" or "11," or

b. The "NIC" value is "9," "10" or "11"

Otherwise, the *Non-Precision* condition is in effect and Vertical Rate information **shall** come from a barometric source, if available.

3.2.1.5.2.7.1.2 "VV Sign" Subfield Encoding

The Sign Bit for Vertical Rate ("VV Sign") subfield is a 1-bit (bit 3 of byte 16) field used to indicate the direction of the "Vertical Rate" subfield. Encoding of this subfield **shall** be as indicated in Table 2-32.

Table 2-32: "Sign Bit for Vertical Rate" Encoding

Coding	Meaning
0	UP
1	DOWN

3.2.1.5.2.7.1.3 "Vertical Rate" Subfield Encoding

The "Vertical Rate" subfield is a 9-bit (bit 4 of byte 16 through bit 4 of byte 17) field is used to report the Vertical Rate (in feet/minute) of the ADS-B transmission device.

Range, Resolution, and No Data encoding of the "Vertical Rate" subfield **shall** be as shown in Table 2-33.

Table 2-33: "Vertical Rate" Encoding

Coding $_{MSB}$(binary)$_{LSB}$	Coding (decimal)	Meaning
0 0000 0000	0	No Vertical Rate information available
0 0000 0001	1	Vertical Rate is ZERO
0 0000 0010	2	Vertical Rate = 64 feet / minute
0 0000 0011	3	Vertical Rate = 128 feet / minute
…	…	…
1 1111 1110	510	Vertical Rate = 32,576 feet / minute
1 1111 1111	511	Vertical Rate > 32,608 feet / minute

Notes:

1. *The encoding shown represents Positive Magnitude data only. Direction is given completely by the VV Sign Subfield.*

2. *Raw data used to establish the "Vertical Rate" subfield will normally have more resolution (i.e., more bits) than that required by the "Vertical Rate" subfield. When converting such data to the "Vertical Rate" subfield, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "Vertical Rate" subfield.*

3. *For codes "0" and "1," the VV Sign Subfield is encoded as ZERO.*

If the Vertical Rate Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "Vertical Rate" subfield **shall** default to a value of ALL ZEROs.

3.2.1.5.2.7.2 Encoding as "A/V Length and Width Code" Form

When the ADS-B Transmitting Subsystem is in the ON-GROUND condition, the "VERTICAL VELOCITY OR A/V SIZE" field **shall** assume the "A/V Length and Width Code" form as shown in Table 2-34. The encoding of the "A/V Length and Width Code" **shall** be as shown in Table 2-35. The encoding of the "Position Offset Applied" (POA) flag shown in Table 2-36 indicates whether the reported position reflects application of a position offset to normalize the ownship navigation sensor position to the ADS-B reference point.

Table 2-34: "A/V Length and Width" Format

Byte 16							Byte 17			
Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 1	Bit 2	Bit 3	Bit 4
A/V Length and Width				**POA**	**Reserved**					

Table 2-35: "Aircraft Length and Width" Encoding

A/V - L/W Code (decimal)	Length Code			Width Code	Length Category (meters)	Width Category (meters)
	Bit 2	Bit 3	Bit 4	Bit 5		
0	0	0	0	0	0 < L < 15	0 < W < 11.5
1				1		11.5 ≤ W < 23
2	0	0	1	0	15 ≤ L < 25	23 ≤ W < 28.5
3				1		28.5 ≤ W < 34
4	0	1	0	0	25 ≤ L < 35	28 ≤ W < 33
5				1		33 ≤ W < 38
6	0	1	1	0	35 ≤ L < 45	34 ≤ W < 39.5
7				1		39.5 ≤ W < 45
8	1	0	0	0	45 ≤ L < 55	38 ≤ W < 45
9				1		45 ≤ W < 52
10	1	0	1	0	55 ≤ L < 65	52 ≤ W < 59.5
11				1		59.5 ≤ W < 67
12	1	1	0	0	65 ≤ L < 75	65 ≤ W < 72.5
13				1		72.5 ≤ W < 80
14	1	1	1	0	L ≥ 75	W < 80
15				1		W ≥ 80

Table 2-36: "Position Offset Applied" Encoding

Coding	Meaning
0	Position Offset Not Applied
1	Position Offset Applied (POA)

3.2.1.5.2.8 "UTC" Field Encoding

The "UTC" field is a 1-bit field (bit 5 of byte 17) that indicates whether the ADS-B Transmitting Subsystem is in the "UTC Coupled" condition or the "Non-UTC Coupled" condition (§4). The encoding of this field **shall** be as indicated in Table 2-37.

If the UTC 1-PPS Timing Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "UTC" field **shall** default to a value of ZERO.

Table 2-37: "UTC" Encoding

Coding	Meaning
0	Non UTC Coupled Condition
1	UTC Coupled Condition

3.2.1.5.2.9 Reserved Bits

Bits 6 through 8 of byte 17 are reserved for future use and **shall** be set to ZERO when the "ADDRESS QUALIFIER" field is set to "0," "1," "4," or "5."

3.2.1.5.2.10 Reserved Byte 18 of Payload Type Zero

Byte 18 of the ADS-B Message Payload definition in Table 2-8, when the Payload Type is ZERO (0) is reserved for future use, and **shall** be set to ALL ZEROs.

3.2.1.5.3 STATE VECTOR Element (For TIS-B)

Format for the STATE VECTOR element used for a TIS-B is defined in Table 2-38. This encoding applies to ADS-B Messages with PAYLOAD TYPE CODES of "0" through "10" only when a TIS-B target is being reported (ADDRESS QUALIFIER value is "2" or "3"). Each of the fields shown is defined in §3.2.1.5.3.1 and §3.2.1.5.3.2.

Table 2-38: Format of STATE VECTOR Element (For TIS-B)

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
.								
.								
5	Latitude (WGS-84)							
6								
7								Longitude (WGS-84)
8								
9								
10								Alt Type
11	Altitude							
12					NIC			
13	A/G State		Reserved	Horizontal Velocity				
14								
15								
16		Vertical Velocity or Aircraft Length/Width Code						
17					**TIS-B Site ID**			
.								
.								

3.2.1.5.3.1 "TIS-B SITE ID" Field Encoding

The "TIS-B SITE ID" field is a 4-bit (bits 5 through 8 of byte 17) field with the MSB as bit 5 and the LSB as bit 8. See Table 2-5 for the encoding of this field.

Notes:

1. *The "UTC" field is not available for TIS-B transmissions. Since TIS-B transmissions come from ground stations, their "UTC Coupled" status is available in the Ground Uplink Message (§3.2.2.1.4).*

2. *The application that uses TIS-B reports is assumed to make appropriate checks for a TIS-B Site ID of value ZERO.*

3.2.1.5.3.2 Encoding for All Other Fields

The encoding of all other fields in the STATE VECTOR Element for TIS-B shown in Table 2-38 is consistent with that of §3.2.1.5.2.1 through §3.2.1.5.2.7.2.

3.2.1.5.4 MODE STATUS Element

Format for the MODE STATUS element is defined in Table 2-39. This encoding **shall** apply to ADS-B Messages with PAYLOAD TYPE CODES of “1” and “3.” Each of the fields shown is defined in the following subparagraphs.

Table 2-39: Format of MODE STATUS Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
. . .								
18	(MSB) Emitter Category and Call Sign Characters#1 and #2 (Base-40 encoding)							
19								(LSB)
20	(MSB) Call Sign Characters #3, #4, and #5 (Base-40 Encoding)							
21								(LSB)
22	(MSB) Call Sign Characters #6, #7, and #8 (Base 40 Encoding)							
23								(LSB)
24	Emergency/Priority Status			UAT MOPS Version			SIL	
25	(MSB) Transmit MSO					(LSB)	Reserved	
26	NACp				NACv			NIC_{BARO}
27	Capability Codes		Operational Modes			True/Mag	CSID	
28	Reserved							
29								
. . .								

Note: *In the above table, where MSB and LSB are not specifically noted, the MSB is the leftmost bit and the LSB is the rightmost bit.*

3.2.1.5.4.1 “EMITTER CATEGORY” Field

The “EMITTER CATEGORY” field is encoded as a radix 40 value in the range of 0-39. The “EMITTER CATEGORY” field **shall** be encoded as shown in Table 2-40.

<u>Table 2-40:</u> "EMITTER CATEGORY" Encoding

Base-40 Digit (decimal)	Meaning	Base-40 Digit (decimal)	Meaning
0	No aircraft type information	20	Cluster Obstacle
1	Light (ICAO) < 15 500 lbs	21	Line Obstacle
2	Small - 15 500 to 75 000 lbs	22	(reserved)
3	Large - 75 000 to 300 000 lbs	23	(reserved)
4	High Vortex Large (e.g., aircraft such as B757)	24	(reserved)
5	Heavy (ICAO) - > 300 000 lbs	25	(reserved)
6	Highly Maneuverable > 5G acceleration and high speed	26	(reserved)
7	Rotocraft	27	(reserved)
8	(Unassigned)	28	(reserved)
9	Glider/sailplane	29	(reserved)
10	Lighter than air	30	(reserved)
11	Parachutist/sky diver	31	(reserved)
12	Ultra light/hang glider/paraglider	32	(reserved)
13	(Unassigned)	33	(reserved)
14	Unmanned aerial vehicle	34	(reserved)
15	Space/transatmospheric vehicle	35	(reserved)
16	(Unassigned)	36	(reserved)
17	Surface vehicle — emergency vehicle	37	(reserved)
18	Surface vehicle — service vehicle	38	(reserved)
19	Point Obstacle (includes tethered balloons)	39	(reserved)

3.2.1.5.4.2 "CALL SIGN" Field

The "CALL SIGN" field consists of eight characters, which must contain only decimal digits 0-9, the capital letters A-Z, and – as trailing pad characters only – the "space" character. The 37 possible different characters are represented as Base-40 digits in the range from 0 to 36. Each character of the "CALL SIGN" field **shall** be encoded as shown in Table 2-41. The left-most character of the Call Sign corresponds to Character #1; the right-most corresponds to Character #8.

If the Call Sign is not available, then all eight characters of the "CALL SIGN" Field **shall** be set to the Base-40 digit code 37.

The 8 characters of the "CALL SIGN" field **shall** be encoded with an identifier appropriate for the Emitter Category, operating rules, and procedures under which the A/V is operating. For aircraft, the "Call Sign" could be an abbreviation of the authorized radiotelephone Call Sign for that aircraft as assigned by ATS, the aircraft registration marking, or other authorized identifier for special operations.

<u>Note</u>: *A Call Sign of less than 8 characters should be padded with spaces in the right-most (trailing) positions. The first character should not be a space.*

Table 2-41: "Call Sign" Character Encoding

Base-40 Digit (decimal)	Character	Base-40 Digit (decimal)	Character
0	0	20	K
1	1	21	L
2	2	22	M
3	3	23	N
4	4	24	O
5	5	25	P
6	6	26	Q
7	7	27	R
8	8	28	S
9	9	29	T
10	A	30	U
11	B	31	V
12	C	32	W
13	D	33	X
14	E	34	Y
15	F	35	Z
16	G	36	SPACE
17	H	37	Not Available
18	I	38	(reserved)
19	J	39	(reserved)

3.2.1.5.4.3 Compressed Format Encoding for "EMITTER CATEGORY" and "CALL SIGN"

Six bytes (byte 18 through byte 23) are used to encode the "EMITTER CATEGORY" and "CALL SIGN" fields. Each of three byte pairs are encoded as the binary equivalent of the Base-40 numeral generated as:

$$B_2 x 40^2 + B_1 x 40 + B_0$$

Where the values B_2, B_1 and B_0 are given in §3.2.1.5.4.3.1 through §3.2.1.5.4.3.3.

3.2.1.5.4.3.1 Bytes 18 and 19

Bytes 18 and 19 **shall** be encoded such that:

B_2 - Represents the "EMITTER CATEGORY" field (§3.2.1.5.4.1)

B_1 - Represents Character #1 of the "CALL SIGN" field (§3.2.1.5.4.2)

B_0 - Represents Character #2 of the "CALL SIGN" field (§3.2.4.5.4.2)

3.2.1.5.4.3.2 Bytes 20 and 21

Bytes 20 and 21 **shall** be encoded such that:

B_2 - Represents Character #3 of the "CALL SIGN" field (§3.2.1.5.4.2)

B_1 - Represents Character #4 of the "CALL SIGN" field (§3.2.1.5.4.2)

B_0 - Represents Character #5 of the "CALL SIGN" field (§3.2.1.5.4.2)

3.2.1.5.4.3.3 Bytes 22 and 23

Bytes 22 and 23 **shall** be encoded such that:

B_2 - Represents Character #6 of the "CALL SIGN" field (§3.2.1.5.4.2)

B_1 - Represents Character #7 of the "CALL SIGN" field (§3.2.1.5.4.2)

B_0 - Represents Character #8 of the "CALL SIGN" field (§3.2.1.5.4.2)

3.2.1.5.4.4 "EMERGENCY/PRIORITY STATUS" Field Encoding

The "EMERGENCY/PRIORITY STATUS" field is a 3-bit (bits 1 through 3 of byte 24) field. The encoding of this field **shall** be as indicated in Table 2-42.

If the Emergency/Priority Status Selection Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "EMERGENCY/PRIORITY STATUS" field **shall** default to a value of ALL ZEROs.

Table 2-42: "EMERGENCY/PRIORITY STATUS" Encoding

Status Code bits $_{MSB}$(Binary)$_{LSB}$	**Status Code bits** (Decimal)	**Meaning**
000	0	No emergency/Not reported
001	1	General emergency
010	2	Lifeguard/medical emergency
011	3	Minimum fuel
100	4	No communications
101	5	Unlawful interference
110	6	Downed Aircraft
111	7	(Reserved)

3.2.1.5.4.5 "UAT MOPS VERSION" Field Encoding

The "UAT MOPS VERSION" field is a 3-bit (bits 4 through 6 of byte 24) field. The encoding of this field **shall** be internally hard coded to ONE (binary 001) by all ADS-B Transmitting Subsystems for equipment complying with this MOPS.

Table 2-43: UAT MOPS Version Number

UAT MOPS VN bits MSB(Binary)LSB	**UAT MOPS Version #** (Decimal)	**Meaning**
000	0	Reserved
001	1	Conformant to the initial UAT MOPS
010	2	Reserved
011	3	Reserved
100	4	Reserved
101	5	Reserved
110	6	Reserved
111	7	Reserved

Note: *The UAT MOPS Version Number of ONE (binary 001) corresponds to an ADS-B MASPS Version Number of ONE.*

3.2.1.5.4.6 "SIL" Field Encoding

The Surveillance Integrity Level ("SIL") field is a 2-bit (bits 7 and 8 of byte 24) field used to define the probability of the integrity containment radius, used in the "NIC" field, being exceeded, without alerting. This includes the effects of airborne equipment condition, which airborne equipment is in use, and which external signals are being used by the navigation source. The encoding of the "SIL" field **shall** be as indicated in Table 2-44.

If the "SIL" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "SIL" field **shall** default to a value of ALL ZEROs.

Table 2-44: "SIL" Encoding.

SIL (binary)	**SIL** (decimal)	**Probability of Exceeding the R_C Integrity Containment Radius Without Detection**	**Comment**
00	0	Unknown	"No Hazard Level" Navigation Source
01	1	1×10^{-3} per flight hour or per operation	"Minor Hazard Level" Navigation Source
10	2	1×10^{-5} per flight hour or per operation	"Major Hazard Level" Navigation Source
11	3	1×10^{-7} per flight hour or per operation	"Severe Major Hazard Level" Navigation Source

Note: *It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used. Thus, for example, if an ADS-B participant reports a NIC code of 0 because four or fewer satellites are available for a GPS fix, there would be no need to change the SIL code until a different navigation source were selected for the positions being reported in the SV report.*

3.2.1.5.4.7 "TRANSMIT MSO" Field Encoding

The "TRANSMIT MSO" field is a 6-bit (bits 1 through 6 of byte 25) field that **shall** be used to encode the 6 LSBs of the Message Start Opportunity (§4.2.1) determined for this message transmission.

3.2.1.5.4.8 Reserved Bits

Bits 7 and 8 of byte 25 are reserved for future use and **shall** be set to ALL ZEROs for equipment conforming to this MOPS.

***Note**: This field is reserved for future reporting of Barometric Altitude Quality (BAQ).*

3.2.1.5.4.9 "NAC_P" Field Encoding

The Navigation Accuracy Category for Position ("NAC_P") field is a 4-bit (bits 1 through 4 of byte 26) field used for applications to determine if the reported State Vector has sufficient position accuracy for the intended use. The encoding of the "NAC_P" field **shall** be as indicated in Table 2-45.

If the "NAC_P" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "NAC_P" field **shall** default to a value of ALL ZEROs.

Table 2-45: "NAC_P" Encoding

NAC_P (binary) MSB LSB	NAC_P (decimal)	95% Horizontal and Vertical Accuracy Bounds (EPU and VEPU)	Comment	Notes
0000	0	EPU ≥ 18.52 km (10 NM)	Unknown accuracy	
0001	1	EPU < 18.52 km (10 NM)	RNP-10 accuracy	1
0010	2	EPU < 7.408 km (4 NM)	RNP-4 accuracy	1
0011	3	EPU < 3.704 km (2 NM)	RNP-2 accuracy	1
0100	4	EPU < 1852 m (1NM)	RNP-1 accuracy	1
0101	5	EPU < 926 m (0.5 NM)	RNP-0.5 accuracy	1
0110	6	EPU < 555.6 m (0.3 NM)	RNP-0.3 accuracy	1
0111	7	EPU < 185.2 m (0.1 NM)	RNP-0.1 accuracy	1
1000	8	EPU < 92.6 m (0.05 NM)	e.g., GPS (with SA)	
1001	9	EPU < 30 m and VEPU < 45 m	e.g., GPS (SA off)	2
1010	10	EPU < 10 m and VEPU < 15 m	e.g., WAAS	2
1011	11	EPU < 3 m and VEPU < 4 m	e.g., LAAS	2
1100	12	(Reserved)		
1101	13	(Reserved)		
1110	14	(Reserved)		
1111	15	(Reserved)		

***Notes**:*

1. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

2. *If geometric altitude is not being reported then the VEPU tests are not assessed.*

3. *The Estimated Position Uncertainty (EPU) used in is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

4. *Likewise, Vertical Estimated Position Uncertainty (VEPU) is a 95% accuracy limit on the vertical position. VEPU is defined as a vertical position limit, such that the probability of the actual vertical position differing from the reported vertical position by more than that limit is 0.05. When reported by a GPS or GNSS system, VEPU is commonly called VFOM (Vertical Figure of Merit).*

3.2.1.5.4.10 "NAC_V" Field Encoding

The Navigation Accuracy Category for Velocity ("NACv") field is a 3-bit (bits 5 through 7 of byte 26) field used for applications to determine if the reported State Vector has sufficient velocity accuracy for the intended use. The "NAC_V" field reflects the least accurate velocity component being transmitted. The "NAC_V" field **shall** be encoded as indicated in Table 2-46.

If the "NAC_V" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "NAC_V" field **shall** default to a value of ALL ZEROs.

Table 2-46: "NAC_V" Encoding.

NAC_V (binary) MSB LSB	**NAC_V** (decimal)	**Horizontal Velocity Error (95%)**	**Vertical Geometric Velocity Error (95%)**
000	0	Unknown or ≥ 10 m/s	Unknown or ≥ 50 feet (15.24 m) per second
001	1	< 10 m/s	< 50 feet (15.24 m) per second
010	2	< 3 m/s	< 15 feet (4.57 m) per second
011	3	< 1 m/s	< 5 feet (1.52 m) per second
100	4	< 0.3 m/s	< 1.5 feet (0.46 m) per second
101	5	(Reserved)	(Reserved)
110	6	(Reserved)	(Reserved)
111	7	(Reserved)	(Reserved)

3.2.1.5.4.11 "NIC_{BARO}" Field Encoding

The Barometric Altitude Integrity Code ("NIC_{BARO}") field is a 1-bit (bit 8 of byte 26) field that indicates whether or not the barometric pressure altitude provided in the State Vector element of the payload has been cross checked against another source of pressure altitude. The "NIC_{BARO}" field **shall** be encoded as indicated in Table 2-47.

If the "NIC_{BARO}" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "NIC_{BARO}" field **shall** default to a value of ZERO.

Table 2-47: "NIC_{BARO}" Encoding

Coding	Meaning
0	Barometric Pressure Altitude has NOT been cross checked
1	Barometric Pressure Altitude has been cross checked

3.2.1.5.4.12 "CAPABILITY CODES" Field Encoding

The "CAPABILITY CODES" field is a 2-bit (bits 1 and 2 of byte 27) field used to indicate the capability of a participant to support engagement in various operations. The "CAPABILITY CODES" field **shall** be encoded as indicated in Table 2-48.

Note: *The Target State (TS) Report Capability flag, the TC Report capability level and the ARV Report Capability flag can be derived from the UAT transmissions of A1, A2 and A3 system participants. Reference RTCA Document DO-242A, Table 3.4(d) and 3.4(e).*

Table 2-48: "CAPABILITY CODES" Encoding

Byte #	Bit #	Encoding
Byte 27	Bit 1	CDTI Traffic Display Capability. 0 = NO 1 = YES
	Bit 2	TCAS/ACAS Installed and Operational. 0 = NO 1 = YES

3.2.1.5.4.12.1 "CDTI Traffic Display Capability" Subfield

The Capability Code for "Cockpit Display of Traffic Information (CDTI) traffic display capability" **shall** be set to ONE if the transmitting aircraft has the capability of displaying nearby traffic on a CDTI. Otherwise, this code **shall** be ZERO.

If the "CDTI Traffic Display Capability" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "CDTI Traffic Display Capability" field **shall** default to a value of ZERO.

3.2.1.5.4.12.2 "TCAS/ACAS Installed and Operational" Subfield

The Capability Code for "TCAS/ACAS installed and operational" **shall** be set to ONE if the transmitting aircraft is fitted with a TCAS (ACAS) computer and that computer is turned on and operating in a mode that can generate Resolution Advisory (RA) alerts. Otherwise, this Capability Code **shall** be ZERO.

If the "TCAS/ACAS installed and operational" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "TCAS/ACAS installed and operational" field **shall** default to a value of ZERO.

3.2.1.5.4.13 "OPERATIONAL MODES" Field Encoding

The "OPERATIONAL MODES" field is a 3-bit (bits 3 through 5 of byte 27) field used to indicate the capability of a participant to support engagement in various operations. The "OPERATIONAL MODES" field **shall** be encoded as indicated in Table 2-49.

Table 2-49: "OPERATIONAL MODES" Encoding

Byte #	Bit #	Encoding
Byte 27	Bit 3	TCAS/ACAS Resolution Advisory Active Flag. 0 = NO 1 = YES
	Bit 4	IDENT Switch Active Flag. 0 = NOT Active (> 20 seconds since activated by pilot) 1 = Active (<= 20 seconds since activated by pilot)
	Bit 5	"Receiving ATC Services" Flag 0 = NOT Receiving ATC Services 1 = Receiving ATC Services

3.2.1.5.4.13.1 "TCAS/ACAS Resolution Advisory" Flag

A transmitting ADS-B participant **shall** set the TCAS/ACAS Resolution Advisory Active Flag to ONE in the messages that it transmits to support the MS report so long as a TCAS/ACAS resolution advisory is in effect. At all other times, the transmitting ADS-B participant **shall** set the TCAS/ACAS Resolution Advisory Active Flag to ZERO.

If the "TCAS/ACAS Resolution Advisory" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "TCAS/ACAS Resolution Advisory" field **shall** default to a value of ZERO.

3.2.1.5.4.13.2 "IDENT Switch Active" Flag

The "IDENT Switch Active" Flag is activated by an IDENT switch. Initially, the "IDENT switch active" code is ZERO. Upon activation of the IDENT switch, this flag **shall** be set to ONE in all scheduled ADS-B Messages containing the MODE STATUS element for an interval of 20 seconds +/-4 seconds. After the time interval expires, the flag **shall** be set to ZERO.

Note: *This allows an ATC ground station 4-5 reception opportunities to receive the IDENT indication.*

If the "IDENT Switch Active" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "IDENT Switch Active" field **shall** default to a value of ZERO.

3.2.1.5.4.13.3 "Receiving ATC Services" Flag

The "Receiving ATC Services" flag is based on a pilot setting. This flag **shall** be set to ONE to indicate that the transmitting ADS-B participant is receiving ATC services; when not receiving ATC services, a transmitting ADS-B participant should set this flag to ZERO.

If the "Receiving ATC Services" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "Receiving ATC Services" field **shall** default to a value of ZERO.

Note: *This provides for a ground ATC system to identify an aircraft that is receiving ATC services, similar to an SSR transponder providing a squawk code of other than "1200."*

3.2.1.5.4.14 "True/Magnetic Heading" Flag

The "True/Magnetic Heading" Flag in the Mode-Status Element is a one-bit field (bit 6 of byte 27) which **shall** be set to ZERO to indicate that heading is reported referenced to true north, or set to ONE to indicate that heading is reported referenced to magnetic north. This "True/Magnetic Heading" Flag supports the "Heading/Track Indicator" Flag in the TARGET STATE Element defined in §3.2.1.5.6.1.1.

If the "True/Magnetic Heading" Flag field is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "True/Magnetic Heading" Flag field **shall** default to a value of ZERO.

3.2.1.5.4.15 Call Sign Identification (CSID)

The Call Sign Identification (CSID) Flag in the Mode Status Element is a one-bit field (bit 7 of byte 27) which **shall** be set to ONE (1) in this version of the MOPS.

3.2.1.5.4.16 Reserved Bits

This Reserved Bits field is a 17-bit (bit 8 of byte 27 through bit 8 of byte 29) field used that may be used in the future to indicate the capability of a participant to support engagement in various operations. This Reserved Bits field is reserved for future use and **shall** be set to ALL ZEROs.

3.2.1.5.5 AUXILIARY STATE VECTOR Element

Format for the AUXILIARY STATE VECTOR element is defined in Table 2-50. This encoding **shall** apply to ADS-B Messages with "PAYLOAD TYPE CODES" of "1," "2," "5," and "6." Each of the fields shown is defined in the following subparagraphs.

Table 2-50: Format of AUXILIARY STATE VECTOR Element

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
. . .								
30	(MSB)			**Secondary Altitude**				
31				(LSB)				
32								
33				**Reserved**				
34								
. . .								

3.2.1.5.5.1 "SECONDARY ALTITUDE" Field Encoding

The "SECONDARY ALTITUDE" field is a 12-bit (bit 1 of byte 30 through bit 4 of byte 31) field used to encode either the geometric altitude or barometric pressure altitude depending on the setting of the "ALTITUDE TYPE" field (§3.2.1.5.2.2). The altitude encoded in the "SECONDARY ALTITUDE" field is the opposite type to that specified by the "ALTITUDE TYPE" field. The encoding **shall** be consistent with that used for "ALTITUDE" described in Table 2-14.

3.2.1.5.5.2 Reserved Bits

Bit 5 of byte 31 through bit 8 of byte 34 are reserved for future use, and **shall** be set to ALL ZEROs.

Note: *This field is reserved for future definition to contain either Air-Referenced Velocity or perhaps wind vector and temperature.*

3.2.1.5.6 TARGET STATE Element (Payload Type Codes "3" and "4")

Format for the TARGET STATE element is defined in Table 2-51. This encoding **shall** apply to ADS-B Messages with "PAYLOAD TYPE CODES" of "3" and "4."

Table 2-51: Format of TARGET STATE Element (Payload Type Codes "3" and "4")

Payload Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
.								
.								
30	Target Heading or Track Angle							
31								
32	Target Altitude							
33								
.								
.								

3.2.1.5.6.1 "TARGET HEADING or TRACK ANGLE" Field Encoding

The "TARGET HEADING OR TRACK ANGLE" field is composed of subfields as indicated in Table 2-52.

Table 2-52: "TARGET HEADING OR TRACK ANGLE" Format

Byte 30							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
Hdg/Trk	**Target Source Indicator (H).**		**Mode Indicator (H)**		**Reserved**	(MSB)	
Byte 31							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	
-- Track Heading or Track Angle --						(LSB)	

3.2.1.5.6.1.1 "Heading/Track Indicator" Flag Encoding

The "Heading/Track Indicator" flag (bit 1 of byte 30) **shall** be set to ZERO to indicate that the "Target Heading or Track Angle" subfield conveys target heading, or ONE to indicate that it conveys target track angle. The reference direction (true north or magnetic north) is conveyed in the "True/Magnetic Heading Flag" of the Mode Status Element referenced in §3.2.1.5.4.14.

If this indication is present in the UAT Transmitting System, and if the "Heading/Track Indicator" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 2-64, then the "Heading/Track Indicator" field **shall** default to a value of ZERO.

3.2.1.5.6.1.2 "Target Source Indicator (Horizontal)" Subfield Encoding

The "Target Source Indicator (Horizontal)" subfield is a 2-bit (bits 2 and 3 of byte 30) field that indicates the source of Target Heading/Track Angle information. The encoding of this field **shall** be as indicated in Table 2-53.

Table 2-53: "Target Source Indicator (Horizontal) Encoding

Bit 2, Byte 30	Bit 3, Byte 30	Encoding (decimal)	Meaning
0	0	0	No Valid Horizontal Target State data is available
0	1	1	Autopilot control panel selected value, such as Mode Control Panel (MCP) or Flight Control Unit (FCU)
1	0	2	Maintaining current heading or track angle (e.g., autopilot mode select)
1	1	3	FMS/RNAV system (indicates track angle specified by leg type)

If the Target Source Indicator (Horizontal) Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "Target Source Indicator (Horizontal)" subfield **shall** default to a value of ALL ZEROs.

3.2.1.5.6.1.3 "Mode Indicator (Horizontal)" Subfield Encoding

The "Mode Indicator (Horizontal)" 2-bit (bits 4 and 5 of byte 30) subfield that reflects the aircraft's state relative to the target heading or track angle. The "Mode Indicator (Horizontal)" subfield **shall** be encoded as indicated in Table 2-54. If this indication is present in the UAT Transmitting System, and if the "Mode Indicator (Horizontal)" subfield is "unavailable" for the "Data Lifetime" timeout listed for this subfield in Table 2-64, then the "Mode Indicator (Horizontal)" subfield **shall** default to a value of ZERO.

Table 2-54: "Mode Indicator (Horizontal)" Subfield Encoding

Coding (binary)	Coding (decimal)	Meaning
00	0	Mode Indicator Not Available
01	1	Target Heading or Track Angle being Acquired
10	2	Target Heading or Track Angle is Captured or is being Maintained
11	3	Reserved

3.2.1.5.6.1.4 Reserved Bits

Bit 6 of byte 30 is reserved for future use and **shall** always be set to ZERO.

3.2.1.5.6.1.5 "Target Heading or Track Angle" Subfield Encoding

The "Track Angle/Heading" subfield is a 9-bit (bit 7 of byte 30 through bit 7 of byte 31) subfield that **shall** be used to report the Track Angle or Heading of the ADS-B Transmitting Subsystem as shown in Table 2-55.

If a source for this subfield is present in the UAT Transmitting System, and if the "Track Angle/Heading" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 2-64, then both the "Track Angle/Heading" field and the Target Source Indicator (Horizontal) **shall** default to a value of ALL ZEROs.

Table 2-55: "Target Heading or Track Angle" Encoding

Coding MSB(binary)LSB	**Coding** (decimal)	**Meaning**
0 0000 0000	0	Track Angle/Heading is ZERO degrees
0 0000 0001	1	Track Angle/Heading = 0.703125 degrees
0 0000 0010	2	Track Angle/Heading = 1.406250 degrees
…	…	…
1 1111 1110	510	Track Angle/Heading = 358.593750 degrees
1 1111 1111	511	Track Angle/Heading = 359.296875 degrees

Note: *Raw data used to establish the "Target Heading or Track Angle" subfield will normally have more resolution (i.e., more bits) than that required by the "Target Heading or Track Angle" subfield. When converting such data to the "Target Heading or Track Angle" subfield, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "Target Heading or Track Angle" subfield.*

3.2.1.5.6.2 "TARGTET ALTITUDE" Field Encoding

The "TARGET ALTITUDE" field is a 17-bit (bit 8 of byte 31 through bit 8 of byte 33) field composed of subfields as indicated in Table 2-56.

Table 2-56: "TARGET ALTITUDE" Format

Byte 31							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
							Target Alt. Type
Byte 32							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
Target Source Indicator (V)		**Mode Ind. (V)**		**Target Altitude Capability**		(MSB)	
Byte 33							
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
-- Target Altitude --							(LSB)

3.2.1.5.6.2.1 "Target Altitude Type" Flag Encoding

The "Target Altitude Type" flag is a 1-bit (bit 8 of byte 31) field that indicates whether the target altitude is barometric pressure altitude or flight level (used for target altitudes above the transition level between altitude types), or a locally corrected altitude (used for target altitudes below the transition level). The "Target Altitude Type" **shall** be encoded as indicated in Table 2-57.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude Type" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 2-64, then the "Target Altitude Type" field **shall** default to a value of ZERO.

Note: *This flag is set based on the relationship of the target altitude to the "transition level."*

Table 2-57: Target Altitude Type Values

Value	Meaning
0	Pressure Altitude ("Flight Level") – target altitude is above transition level
1	Baro-Corrected Altitude ("MSL") – target altitude is below transition level

3.2.1.5.6.2.2 "Target Source Indicator (Vertical)" Subfield Encoding

The "Target Source Indicator (Vertical)" is a 2-bit (bits 1 and 2 of byte 32) field that indicates the source of Target Altitude information. The encoding of this field **shall** be as indicated in Table 2-58.

Table 2-58: "Target Source Indicator (Vertical)" Encoding

Bit 1, Byte 32	Bit 2, Byte 32	(decimal)	Meaning
0	0	0	No Valid Vertical Target State data is available
0	1	1	Autopilot Control Panel selected value such as a Mode Control Panel (MCP) or Flight Control Unit (FCU)
1	0	2	Holding Altitude
1	1	3	FMS or RNAV system

If the Target Source Indicator (Vertical) Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 2-64, then the "Target Source Indicator (Vertical)" subfield **shall** default to a value of ALL ZEROs.

3.2.1.5.6.2.3 "Mode Indicator (Vertical)" Subfield Encoding

The "Mode Indicator (Vertical)" is a 2-bit (bit 3 and 4 of byte 32) subfield that reflects the aircraft's state relative to the target altitude. The "Mode Indicator (Vertical)" subfield **shall** be encoded as indicated in Table 2-59. If this indication is present in the UAT Transmitting

System, and if the "Mode Indicator (Vertical)" is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 2-64, then the "Mode Indicator (Vertical)" subfield **shall** default to a value of ZERO.

Table 2-59: "Mode Indicator (Vertical)" Subfield Encoding

Coding (binary)	Coding (decimal)	Meaning
00	0	Mode Indicator Not Available
01	1	Target Altitude being Acquired
10	2	Target Altitude Captured or Maintained
11	3	Reserved

3.2.1.5.6.2.4 "Target Altitude Capability" Subfield Encoding

The "Target Altitude Capability" is a 2-bit (bit 5 and 6 of byte 32) field that describes the value occupying the "Target Altitude" subfield. The encoding of this field **shall** be as indicated in Table 2-60.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude Capability" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 2-64, then the "Target Altitude Capability" field **shall** default to a value of ALL ZEROs.

Table 2-60: "Target Altitude Capability" Encoding

Bit 5, Byte 32	Bit 6, Byte 32	Meaning
0	0	Target Altitude Capability Not Available
0	1	Capability for either holding altitude, or for autopilot control panel selected altitude
1	0	Capability for either holding altitude, for autopilot control panel selected altitude, or for any FMS/RNAV level-off altitude
1	1	Capability for holding altitude only

3.2.1.5.6.2.5 "Target Altitude" Subfield Encoding

"Target Altitude" is a 10-bit (bit 7 of byte 32 through bit 8 of byte 33) field that is the aircraft's next intended level flight altitude if in a climb or descent, or its current intended altitude if commanded to hold altitude. The encoding of this field **shall** be as indicated in Table 2-61.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude" subfield is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 2-64, then both the "Target Altitude" and the Target Source Indicator (Vertical) subfields **shall** default to a value of ALL ZEROs

Table 2-61: "Target Altitude" Encoding

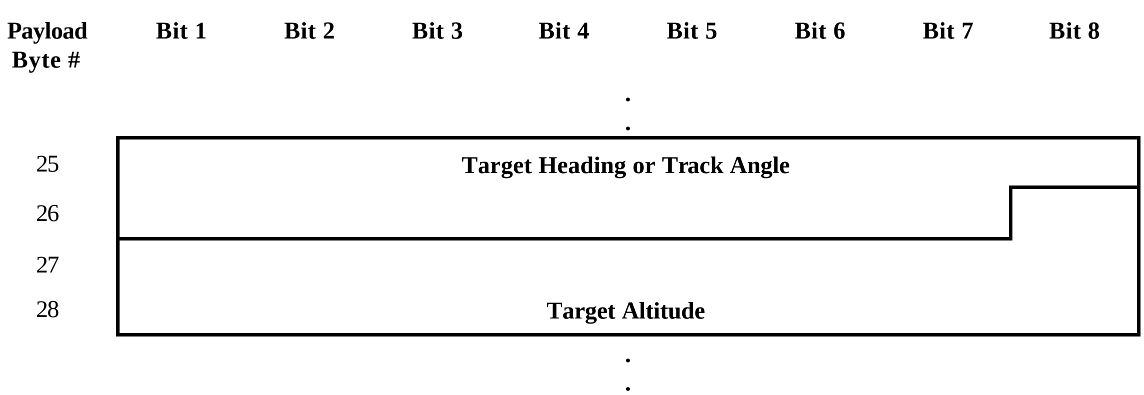
Coding MSB(binary)LSB	Coding (decimal)	Meaning
00 0000 0000	0	Target Altitude information unavailable
00 0000 0001	1	Target Altitude = -1000 feet
00 0000 0010	2	Target Altitude = -900 feet
…	…	…
00 0000 1010	10	Target Altitude = -100 feet
00 0000 1011	11	Target Altitude = ZERO feet
00 0000 1100	12	Target Altitude = 100 feet
…	…	…
11 1111 1110	1022	Target Altitude = 101,100 feet
11 1111 1111	1023	Target Altitude > 101,150 feet

Note: *Raw data used to establish the Target Altitude subfield will normally have more resolution (i.e., more bits) than that required by the Target Altitude subfield. When converting such data to the Target Altitude subfield, the accuracy of the data shall be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the Target Altitude subfield.*

3.2.1.5.7 TARGET STATE Element (Payload Type Code "6")

Format for the TARGET STATE element is defined in Table 2-62. This encoding **shall** apply to ADS-B Messages with "PAYLOAD TYPE CODES" of "6." Each of the fields shown are defined in §3.2.1.5.6.1.5 through §3.2.1.5.6.2.5 with the exception of the byte offset indicated in Table 2-62.

Table 2-62: Format of TARGET STATE Element



3.2.1.5.8 TRAJECTORY CHANGE Element

This element contains 96 bits (bytes 18 through 29) that are reserved for future definition. Equipment conforming to this MOPS **shall** insert ALL ZEROs in this element whenever present in a transmitted message. See the UAT MOPS, RTCA DO-282, Appendix L to see how this reserved field could be used to meet the requirements of reporting TCR+0 and TCR+1 in the future.

3.2.2 Ground Uplink Message Payload

The Ground Uplink Message 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 2-4. Bytes and bits are fed to the interleaving process with the most significant byte, byte #1, transmitted first, and within each byte, the most significant bit, bit #1, transmitted first.

<u>Table 2-4:</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	Reserved	App Data Valid	(MSB)		**Slot ID**		(LSB)
8	(MSB)	**TIS-B Site ID**		(LSB)		**Reserved**		
9								
				Application Data				
432								

3.2.2.1 UAT-Specific Header

3.2.2.1.1 "GROUND STATION LATITUDE" Field Encoding

The "GROUND STATION LATITUDE" field is a 23-bit (bit 1 of byte 1 through bit 7 of byte 3) field used to identify the latitude of the ground station. The encoding of this field by the ground station will be the same as defined for latitude information in the ADS-B Message (§3.2.1.5.2.1).

<u>Note:</u> *The resolution of this field has been selected to support a potential passive ranging function.*

3.2.2.1.2 "GROUND STATION LONGITUDE" Field Encoding

The "GROUND STATION LONGITUDE" field is a 24-bit (bit 8 of byte 3 through bit 7 of byte 6) field used to identify the longitude of the ground station. The encoding of this field by the ground station will be the same as defined for longitude information in the ADS-B Message (§3.2.1.5.2.1).

Note: *The resolution of this field has been selected to support a potential passive ranging function.*

3.2.2.1.3 "POSITION VALID" Field Encoding

The "POSITION VALID" field is a 1-bit (bit 8 of byte 6) field used to indicate whether or not the position in the header is valid. An encoding of ONE represents a VALID position. An encoding of ZERO represents an INVALID position.

3.2.2.1.4 "UTC Coupled" Field Encoding

The "UTC Coupled" field is a 1-bit (bit 1 of byte 7) field used to indicate whether or not the ground station 1 Pulse Per Second timing is valid. An encoding of ONE represents VALID timing. An encoding of ZERO represents INVALID timing.

3.2.2.1.5 Reserved Bits

Bit 2 of byte 7 is reserved for future use and will always be set to ZERO.

3.2.2.1.6 "APPLICATION DATA VALID" Field Encoding

The "APPLICATION DATA VALID" field is a 1-bit (bit 3 of byte 7) field used to indicate whether or not the Application Data is valid for operational use. An encoding of ONE represents VALID Application Data. An encoding of ZERO represents INVALID Application Data.

Notes:

1. *Airborne applications should ignore the Application Data field when this bit is set to INVALID.*

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

3.2.2.1.7 "SLOT ID" Field Encoding

The "SLOT ID" field is a 5-bit (bit 4 through bit 8 of byte 7) field used to 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 do not need 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.*

3.2.2.1.8 "TIS-B SITE ID" Field Encoding

The "TIS-B SITE ID" field is a 4-bit (bits 1, through 4 of byte 8) field used to convey the reusable TIS-B Site ID that is also encoded with each TIS-B transmission as shown in Table 2-5 below:

Table 2-5: 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 transmissions were transmitted from the site located at the Latitude/Longitude encoded in the UAT-Specific Header portion of the Ground Uplink payload. The width of the field was selected based upon analysis of the needs of a potential passive ranging function.*

3.2.2.1.9 Reserved Bits

Bits 5 through 8 of byte 8 are reserved for future use and will be set to ALL ZEROs.

3.2.2.2 Ground Uplink Application Data

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

4 System Timing

4.1 Procedures for Processing of Time Data

UAT equipment derives its timing for transmitter and receiver functions from GPS/GNSS (or equivalent) time sources. The Time of Applicability of the PVT data is presumed to be within +/- 5 milliseconds of the Leading Edge of the Time Mark signal to which it applies. Time Mark information is utilized by the UAT equipment in the following ways:

a. Any extrapolation of Position data **shall** comply with the requirements of §**Error! Reference source not found.** and §**Error! Reference source not found.**.

b. The UAT transmit message timing **shall** comply with the requirements of §4.2.1 and §4.2.2.

c. The UAT receiver time processing **shall** comply with the requirements of §**Error! Reference source not found.**.

Notes:

1. *A possible implementation of the GPS/GNSS Time Mark pulse is illustrated in Figure 2-6, adapted from ARINC Characteristic 743A.*

2. *Determination of time source "equivalence" will be made by appropriate Certification Authorities. Useful information concerning recommended accuracy of such a time source may be found in Appendix E.*

4.1.1 UTC Coupled Condition

The "UTC Coupled" subfield **shall** be set to ONE, except under the conditions discussed in §4.1.2.

Note: *Operation of the UAT system in normal mode presumes GNSS, or equivalent, equipage on system participants to, for example, prevent media access conflict with the UAT ground up-link transmissions. Short term GNSS outages are mitigated by UAT ground infrastructure providing timing information and/or the ability to maintain UAT system timing for a minimum of 20 minutes in the absence of GNSS (§4.1.2[d]). In areas without ground up-link transmissions, there is no media access conflict.*

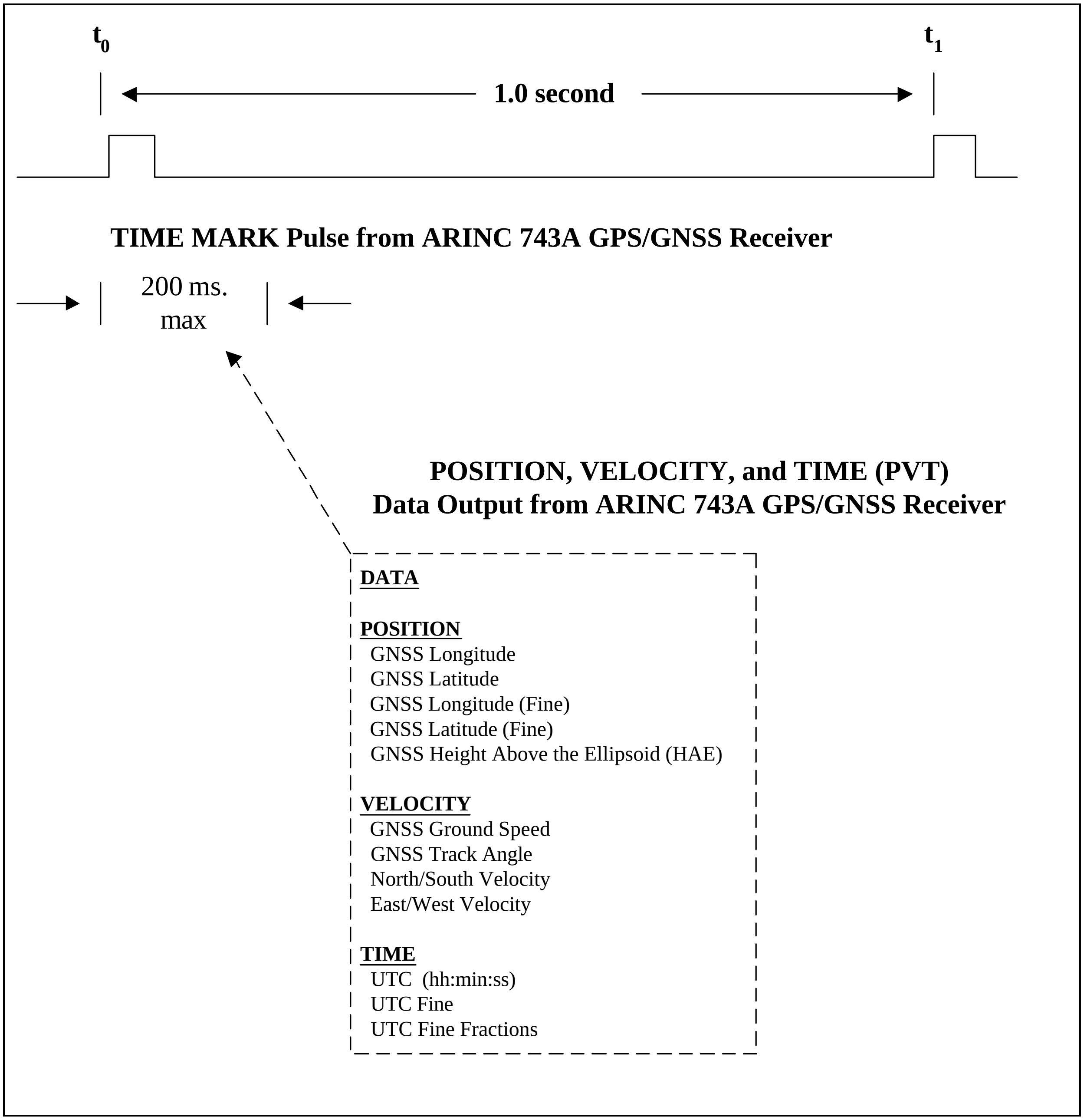


Figure 2-6: GPS/GNSS Time Mark Pulse

4.1.2 Non-UTC Coupled Condition

a. This condition **shall** be entered when the ADS-B equipment has not been provided a GPS/GNSS, or equivalent, time mark. This is not the normal condition; it is a degraded mode of operation.

b. Within 2 seconds of entering the Non-UTC Coupled condition, the UAT equipment **shall** set the “UTC Coupled” subfield to ZERO in any transmitted messages.

c. While in the non-UTC Coupled Condition, Class A0, A1, A2 and A3 equipment with operational receivers **shall** be capable of aligning to within +/- 6 milliseconds of UTC time based upon successful message reception of any Ground Uplink Message with the "UTC Coupled" bit set.

***Note**: This assumes that the Ground Uplink Message is referenced to UTC 1-second epoch.*

d. While in the non-UTC Coupled Condition when Ground Uplink Messages cannot be received, the UAT transmitter **shall** estimate — or "coast" — time through the outage period such that the drift rate of estimated time, relative to actual UTC-coupled time, is no greater than 12 milliseconds in 20 minutes.

e. While in the non-UTC Coupled Condition, ADS-B transmissions **shall** continue.

f. The UAT equipment **shall** change state to the UTC coupled condition within 2 seconds of availability of the UTC coupled source.

Notes:

1. *Item "d" above is consistent with an initial drift rate of 10 PPM in the baud clock over the 12 millisecond air-ground segment guard time. Clock drift can be compensated up to the time coasting begins.*

2. *In the non-UTC Coupled Condition, the estimated 1 second UTC epoch signal does NOT indicate the time of validity of Position, Velocity and Time (PVT) information.*

3. *Any installations of Class A equipment involving separated transmitters and receivers must provide a mechanism to fulfill the requirement stated in subparagraph (c) above.*

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

4.2 ADS-B Media Access Timing

4.2.1 The Message Start Opportunity (MSO)

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

N(0) = 12 L.S.B.'s of the most recent valid "LATITUDE"
N(1) = 12 L.S.B.'s of the most recent valid "LONGITUDE"

where the "LATITUDE" and "LONGITUDE" are as defined in §3.2.1.5.2.1.

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

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

$$R(0) = N(0)$$

1. When in the first frame after power up, and whenever the Vertical Status is determined to be in the AIRBORNE condition, the transmitter **shall** be in the *full MSO range* mode, where the MSO is determined as follows:

   MSO = 752 + R(m)

2. Under all other conditions the transmitter **shall** be in the *restricted MSO range* mode, where the MSO is determined as follows:

   MSO = 752 + R* + R(m)mod800

   With R* = R(k) – R(k)mod800, where "k" is the frame just prior to entering the *restricted MSO range* mode.

Notes:

1. *Retention of N(0) and N(1) in non-volatile memory is required to prevent common MSO selections amongst A/Vs when no valid latitude and longitude is currently available.*

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

3. *The restricted range MSO mode makes the choice of MSO more nearly periodic in order to support certain surface applications.*

4.2.2 Relationship of the MSO to the Modulated Data

The optimum sample point of the first bit of the UAT synchronization sequence at the antenna terminal of the UAT equipment **shall** occur at T_{TX} microseconds after the 1 second UTC epoch according to the following formula:

$$T_{TX} \text{ (microseconds)} = 6000 + (250 \cdot \text{MSO})$$

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. This requirement sets the ultimate timing accuracy of the transmitted messages under the*

UTC Coupled condition. See Appendix E for a discussion of UAT Timing Considerations.

2. *Referencing this measurement to the optimum sampling point is convenient since this is the point in time identified during the synchronization process.*

3. *There is no requirement to demonstrate this relationship when in the non-UTC Coupled condition.*

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