RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #10

Modifications to Appendix A to accommodate the addition of 1090 TIS-B as A.2 in partial response to Action Item 7-6

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SUMMARY
This Working Paper presents Appendix A as it has been modified to make all published section headings conform to A.1.xxx to accommodate the addition of the TIS-B materials as section A.2. All section headings have been modified, as well as all references to all subparagraphs in Appendix A, as well as all references to Appendix A subparagraphs in all other sections of the 1090 MOPS (DO-260).

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Appendix A

Extended Squitter Formats And Coding Definitions

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A.1 ADS-B 1090 MHz Formats and Coding

A.1.1 Introduction

Notes:

1. *This appendix defines the formats and coding for extended squitter ADS-B messages. When extended squitter capability is incorporated into a Mode S transponder, the registers used to contain the extended squitter messages are part of the transponder's Ground-Initiated Comm-B service. This service consists of defined data available on board the aircraft being put into one of the 255 registers (each with a length of 56 bits) in the Mode S transponder by a serving process, e.g. ADS-B, at specified intervals. The Mode S ground interrogator can extract the information from any of these registers at any time and pass it to the ground-based application. In the case of extended squitter, the information in the registers defined for ADS-B are spontaneously broadcast as specified in RTCA/DO-181B.*

2. *If the extended squitter capability is implemented as a non-transponder function, the convention for register numbering does not apply. However, the data content is the same as specified for the transponder case, and the transmit times are as specified in the body of this MOPS.*

A.1.2 Register Allocation

Table A-1: Register Allocation

Register number	Assignment	Minimum update rate
05_{16}	Extended squitter airborne position	0.2 s
06_{16}	Extended squitter surface position	0.2 s
07_{16}	Extended squitter status	1.0 s
08_{16}	Extended squitter identification and type	15.0 s
09_{16}	Extended squitter airborne velocity	0.2 s
$0A_{16}$	Extended squitter event-driven information	variable
10_{16}	Data link capability report	4.0 s (see Note 2)
17_{16}	Common usage capability report	5.0 s
18_{16}-$1F_{16}$	Mode S specific services capability report	5.0 s
20_{16}	Aircraft identification	5.0 s
61_{16}	Extended squitter emergency/priority status	1.0 s
62_{16}	Current Trajectory Change Point	1.7 s (2.2.3.3.2.6.1)
63_{16}	Next Trajectory Change Point	1.7 s (2.2.3.3.2.6.1)
64_{16}	Aircraft operational coordination message	2.0 or 5.0 s (2.2.3.3.2.6.2)
65_{16}	Aircraft operational status	1.7 s (2.2.3.3.2.6.3)
66_{16}-$6F_{16}$	Reserved for extended squitter	

Notes:

1. *The register number is equivalent to the BDS B-Definition Subfield (BDS) value 2.2.14.4.14.b of DO-181B.*

2. *For ADS-B implementations on Mode S transponders, the data link capability report (BDS1,0) is used to indicate Extended Squitter capability (bit 34) and the contents of this register are updated within one second of the data changing and at least every four seconds thereafter.*

3. *Register 0,A is not to be used for GICB or ACAS crosslink readout.*

The details of the data to be entered into the registers assigned for extended squitter shall be as defined in this appendix. Table A-1 specifies the minimum update rates at which the appropriate transponder register(s) shall be reloaded with valid data. If the defined update rate is not maintained, the status bit (if provided) shall indicate that the data in that field are invalid.

A.1.3 General Conventions On Data Formats

A.1.3.1 Validity of Data

The bit patterns contained in the 56-bit transponder registers shall be considered to be valid application data only if:

1. The Mode S specific services capability is present. This is indicated by bit 25 of the data link capability report contained in BDS 1,0 being set to "ONE;"

2. The service corresponding to the application is shown as "supported" by the corresponding bit in the Common Usage Capability Report (BDS 1,7) being set to "ONE" for the extended squitter registers 0,5 to 0,A inclusive.

   Notes:

   1. *The intent of the capability bits in register 1,7 is to indicate that useful data is contained in the corresponding register. For this reason, the bit for a register is cleared if data becomes unavailable (A.1.6.2) and set again when data insertion into the register resumes.*

   2. *A bit set in register 1,8 to 1,C indicates that the application using this register has been installed on the aircraft. These bits are not cleared to reflect a real time loss of an application, as is done for register 1,7.*

3. The data value is valid at the time of extraction. This is indicated by a data field status bit (if provided). When this status bit is set to "ONE," the data field(s) which follow, up to the next status bit, are valid. When this status bit is set to "ZERO," the data field(s) are invalid.

A.1.3.2 Representation of Numerical Data

Numerical data shall be represented as follows:

1. Numerical data are represented as binary numerals. When the value is signed, 2's complement representation is used, and the bit following the status bit is the sign bit.

2. Whenever applicable, the resolution has been either tailored to the corresponding ARINC 429 label or aligned with ICAO documents.

3. Unless otherwise specified, whenever more bits of resolution are available from the data source than in the data field into which that data is to be loaded, the data shall be rounded to the nearest value that can be encoded in that data field.

4. Where ARINC 429 data are used, the ARINC 429 status bits 30 and 31 are replaced with a single status bit, for which the value is VALID or INVALID as follows:

   a) If bits 30 and 31 represent "Failure Warning, No Computed Data" then the status bit shall be set to "INVALID."

   b) If bits 30 and 31 represent "Normal Operation," "plus sign," or "minus sign," or "Functional Test" then the status bit shall be set to "VALID" provided that the data are being updated at the required rate.

   c) If the data are not being updated at the required rate, then the status bit shall be set to "INVALID."

   For interface formats other than ARINC 429, a similar approach is used.

5. In all cases where a status bit is used, it must be set to "ONE" to indicate VALID and to "ZERO" to indicate INVALID.

6. Where the sign bit (ARINC 429 bit 29) is not required for a parameter, it has been actively excluded.

7. Bits are numbered in the Message, Comm-B Field in order of their transmission, beginning with bit 1. If numerical values are encoded by groups of bits (fields), then the first bit transmitted is the most significant bit (MSB) unless otherwise stated.

Note: *BDS A, B is equivalent to register number AB_{16}.*

A.1.4 Extended Squitter Formats

A.1.4.1 Format Type Codes

The first 5-bit field in every Mode S extended squitter message shall contain the format type. The format type shall differentiate the messages into several classes: airborne position, airborne velocity, surface position, identification, aircraft intent, aircraft state, etc. In addition, the format type shall encode the measurement precision category into classes based on the Horizontal Protection Limit (HPL) or horizontal position error of the source used for the position report. The format type shall also differentiate the airborne messages as to the type of their altitude measurements: barometric pressure altitude or GNSS height (HAE). The 5-bit encoding for format type shall conform to the definition contained in Table A-2.

Table A-2: Format Type Codes

"TYPE" Subfield Code Definitions (DF = 17 or 18)					
Type Code	**Format**	**Horizontal Protection Limit, HPL**	**95% Containment Radius, m and n, On Horizontal and Vertical Position Error**	**Altitude Type**	**NUC_P**
0	No Position Information			Baro Altitude or No Altitude Information	0
1	Identification (Category Set D)			*Not Applicable*	
2	Identification (Category Set C)			*Not Applicable*	
3	Identification (Category Set B)			*Not Applicable*	
4	Identification (Category Set A)			*Not Applicable*	
5	Surface Position	HPL < 7.5 m	μ< 3 m	No Altitude Information	9
6	Surface Position	HPL < 25 m	3 m ≤ μ < 10 m	No Altitude Information	8
7	Surface Position	HPL < 185.2 m (0.1 NM)	10 m ≤ μ < 92.6 m (0.05 NM)	No Altitude Information	7
8	Surface Position	HPL ≥ 185.2 m (0.1 NM)	(0.05 NM) 92.6 m ≤ μ	No Altitude Information	6
9	Airborne Position	HPL < 7.5 m	μ < 3 m	Baro Altitude	9
10	Airborne Position	7.5 m ≤ HPL < 25 m	3 m ≤ μ < 10 m	Baro Altitude	8
11	Airborne Position	25 m ≤ HPL < 185.2 m (0.1 NM)	10 m ≤ μ < 92.6 m (0.05 NM)	Baro Altitude	7
12	Airborne Position	185.2 m (0.1 NM) ≤ HPL < 370.4 m (0.2 NM)	92.6 m (0.05 NM) ≤ μ < 185.2 m (0.1 NM)	Baro Altitude	6
13	Airborne Position	380.4 m (0.2 NM) ≤ HPL < 926 m (0.5 NM)	185.2 m (0.1 NM) ≤ μ < 463 m (0.25 NM)	Baro Altitude	5
14	Airborne Position	26 m (0.5 NM) ≤ HPL < 1852 m (1.0 NM)	463 m (0.25 NM) ≤ μ < 926 m (0.5 NM)	Baro Altitude	4
15	Airborne Position	1852 m (1.0 NM) ≤ HPL < 3704 m (2.0 NM)	926 m (0.5 NM) ≤ μ < 1.852 km (1.0 NM)	Baro Altitude	3
16	Airborne Position	7.704 km (2.0 NM) ≤ HPL < 18.52 km (10 NM)	1.852 km (1.0 NM) ≤ μ < 9.26 km (5.0 NM)	Baro Altitude	2
17	Airborne Position	18.52 km (10 NM) ≤ HPL < 37.04 km (20 NM)	9.26 km (5.0 NM) ≤ μ < 18.52 km (10.0 NM)	Baro Altitude	1
18	Airborne Position	HPL ≥ 37.04 km (20 NM)	8.52 km (10.0 NM) ≤ μ	Baro Altitude	0
19	Airborne Velocity	*Not Applicable*	*Not Applicable*	*Difference between "Baro Altitude" and "GNSS Height (HAE) or GNSS Alr (MSL)"(A.1.4.5.6)*	*N/A*
20	Airborne Position	HPL < 7.5 m	μ < 3 m and ν < 4 m	GNSS Height (HAE)	9
21	Airborne Position	HPL < 25 m	μ < 10 m and ν < 15 m	GNSS Height (HAE)	8
22	Airborne Position	HPL ≥ 25 m	μ ≥ 10 m or ν ≥ 15 m	GNSS Height (HAE)	**TBD**
23	Reserved for Test Purposes				
24	Reserved for Surface System Status				
25 - 27	Reserved				
28	Extended Squitter Aircraft Status				
29	Current/Next Trajectory Change Point				
30	Aircraft Operational coordination				
31	Aircraft Operational Status				

Notes:

1. *"Baro-Altitude" refers to barometric pressure altitude, relative to a standard pressure of 1013.25 millibars (29.92 in Hg). It does not refer to baro corrected altitude.*

2. *The GNSS height (HAE)) defined in Type Codes 20 to 22 is used when baro altitude is not available.*

3. *The term "broadcast" as used in this appendix refers to a spontaneous transmission by the transponder. This is distinct from the Comm-B broadcast protocol.*

4. *The 95% containment limit, m, on horizontal position error is derived from ARINC 429 label 247, HFOM (Horizontal Figure of Merit). Likewise, the 95% containment limit, n, on vertical position error is derived from ARINC 429 label 136, VFOM (Vertical Figure of Merit). The horizontal protection level, HPL, is derived from ARINC 429 label 130, which is variously called HIL (Horizontal Integrity Limit) or HPL (Horizontal Protection Level).*

A.1.4.2 Airborne Position Format

The airborne position squitter shall be formatted as specified in the definition of register 0,5.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.2.1 Compact Position Reporting (CPR) Format (F)

In order to achieve coding that is unambiguous world wide, CPR shall use two format types, known as "**even**" and "**odd**." This one-bit field (bit 22) shall be used to define the CPR format type. A CPR Format equal to ZERO (0) shall denote an "**even**" format coding, while a CPR Format equal to ONE (1) shall denote an "**odd**" format coding (A.1.7.7).

A.1.4.2.2 Time Synchronization (T)

This one-bit field (bit 21) shall indicate whether or not the time of applicability of the message is synchronized with UTC time. T equal to zero shall denote that the time is not synchronized to UTC. T equal to one shall denote that time of applicability is synchronized to UTC time. Synchronization shall only be used for airborne position messages having the top two horizontal position precision categories (Type Codes 9, 10, 20 and 21).

When T=1, the time of validity in the airborne message format shall be encoded in the 1-bit F field which (in addition to CPR format type) shall indicate the 0.2 second time tick for UTC time of position validity. The F bit shall alternate between 0 and 1 for successive 0.2 second time ticks, beginning with F=0 when the time of applicability shall be an exact even-numbered UTC second.

A.1.4.2.3 Latitude/Longitude

The latitude/longitude field in the airborne position message shall be a 34-bit field containing the latitude and longitude of the aircraft airborne position. The latitude and longitude shall each occupy 17 bits. The airborne latitude and longitude encoding shall contain airborne CPR-encoded values in accordance with A.1.7. The unambiguous range for the local decoding of airborne messages shall be 666 km (360 NM). The positional accuracy maintained by the airborne CPR encoding shall be approximately 5.1 meters.

Note: *The latitude/longitude encoding is also a function of the CPR format value (the "F" bit) described above.*

A.1.4.2.3.1 Extrapolating Position (When T=1)

If T is set to one, airborne position messages with Type Codes 9, 10, 20 and 21 shall have times of applicability that are exact 0.2 UTC second epochs. In that case, the F bit shall be 0 if the time of applicability is an even-numbered 0.2 second UTC epoch, or 1 if the time of applicability is an odd-numbered 0.2 second epoch.

Note 1: *Here, an "even-numbered 0.2 second epoch" means an epoch that occurs an even number of 200-millisecond time intervals after an even-numbered UTC second. An "odd-numbered 0.2 second epoch" means an epoch that occurs an odd number of 200-millisecond time intervals after an even-numbered UTC second. Examples of even-numbered 0.2 second UTC epochs are 12.0 s, 12.4 s, 12.8 s, 13.2 s, 13.6 s, etc. Examples of odd-numbered UTC epochs are 12.2 s, 12.6 s, 13.0 s, 13.4 s, 13.8 s, etc.*

The CPR-encoded latitude and longitude that are loaded into the airborne position register shall comprise an estimate of the A/V position at the time of applicability of that latitude and longitude, which is an exact 0.2 second UTC epoch. The register shall be loaded no earlier than 150 ms before the time of applicability of the data being loaded, and no later than 50 ms before the time of applicability of that data.

This timing ensures that the receiving ADS-B system may easily recover the time of applicability of the data in the airborne position message, as follows:

- If F = 0, the time of applicability shall be the nearest even-numbered 0.2 second UTC epoch to the time that the airborne position message is received.

- If F = 1, the time of applicability shall be the nearest odd-numbered 0.2 second UTC epoch to the time that the airborne position message is received.

Note 2: *If the airborne position register is loaded every 200 ms, the ideal time to load that register would be 100 ms before the time of applicability of the data being loaded. The register would then be re-loaded, with data* *applicable at the next subsequent 0.2 second UTC epoch, 100 ms before that next subsequent 0.2 second epoch. That way, the time of transmission of an airborne position message would never differ by more than 100 ms from the time of applicability of the data in that message. By specifying "100 ms ± 50 ms" rather than 100 ms exactly, we allow some tolerance for variations in implementation.*

The position data that is loaded into the airborne position register shall be an estimate of the A/V position at the time of applicability.

Note 3: *The position may be estimated by extrapolating the position from the time of validity of the fix (included in the position fix) to the time of applicability of the data in the register (which, if T=1, is an exact 0.2 UTC time tick). This may be done by a simple linear extrapolation using the velocity provided with the position fix and the time difference between the position fix validity time and the time of applicability of the transmitted data. Alternatively, other methods of estimating the position, such as alpha-beta trackers or Kalman filters, may be used.*

Every 200 ms, the contents of the position registers shall be updated by estimating the A/V position at the next subsequent 0.2 second UTC epoch. This process shall continue with new position fixes as they become available from the source of navigation data.

A.1.4.2.3.2 Extrapolating Position (When T=0)

T shall be set to zero if the time of applicability of the data being loaded into the position register is not synchronized to any particular UTC epoch. In that case, the position register shall be re-loaded with position data at intervals that are no more than 200 ms apart. The position being loaded into the register shall have a time of applicability that is never more than 200 ms different from any time during which the register holds that data.

Note: *This may be accomplished by loading the airborne position register at intervals that are, on average, no more than 200 ms apart, with data for which the time of applicability is between the time the register is loaded and the time that it is loaded again. (Shorter intervals than 200 ms are permitted, but not required.)*

If T is zero, receiving ADS-B equipment shall accept airborne position messages as being current as of the time of receipt. The transmitting ADS-B equipment shall re-load the airborne position register with updated estimates of the A/V position, at intervals that are no more than 200 ms apart. The process shall continue with new position reports as they become available.

A.1.4.2.3.3 Time-Out When New Position Data is Unavailable

In the event that the navigation input ceases, the extrapolation described in subparagraphs A.1.4.2.3.1 and A.1.4.2.3.2 above shall be limited to no more than two seconds. At the end of this timeout of two seconds, all fields of the airborne position register, except the altitude field, shall be cleared (set to zero).

Note: *The altitude field, bits 9 to 20 of the register, would only be cleared if current altitude data were no longer available.*

With the appropriate register fields cleared, the zero type code field shall serve to notify ADS-B receiving equipment that the data in the latitude and longitude fields are invalid.

A.1.4.2.4 Altitude

This 12-bit field shall provide the aircraft altitude. Depending on the Type Code, this field shall contain either:

1. Barometric altitude encoded in 25 or 100 foot increments (as indicated by the Q Bit) or,

2. GNSS height above ellipsoid (HAE).

Note: *GNSS altitude MSL is not accurate enough for use in the position report.*

A.1.4.2.5 Single Antenna Flag (SAF)

This one-bit field shall indicate the type of antenna system that is being used to transmit extended squitters. SAF equal to ONE shall signify a single transmit antenna. SAF equal to ZERO shall signify a dual transmit antenna system. At any time that the diversity configuration cannot guarantee that both antenna channels are functional, then the SAF Subfield shall be set to ONE.

A.1.4.3 Surface Position Format

The surface position squitter shall be formatted as specified in the definition of register 0,6.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.3.1 Movement

This 7-bit field shall provide information on the ground speed of the aircraft. A non-linear scale shall be used as defined in the Table A-3, where speeds are given in km/h (kt).

Table A-3: Coding of the Movement Field

Encoding	*Meaning*	*Quantization*
0	no information available	
1	aircraft stopped (ground speed < 0.2315 km/h (0.125 kt))	
2-8	0.2315 km/h (0.125 kt) ≤ ground speed < 1.852 km/h (1 kt)	(in 0.2315 km/h (0.125 kt) steps)
9-12	1.852 km/h (1 kt) ≤ ground speed < 3.704 km/h (2 kt)	(in 0.463 km/h (0.25 kt) steps)
13-38	3.704 km/h (2 kt) ≤ ground speed < 27.78 km/h (15 kt)	(in 0.926 km/h (0.5 kt) steps)
39-93	27.78 km/h (15 kt) ≤ ground speed < 129.64 km/h (70 kt)	(in 1.852 km/h (1.0 kt) steps)
94-108	129.64 km/h (70 kt) ≤ ground speed < 185.2 km/h (100 kt)	(in 3.704 km/h (2.0 kt) steps)
109-123	185.2 km/h (100 kt) ≤ ground speed < 324.1 km/h (175 kt)	(in 9.26 km/h (5.0 kt) steps)
124	ground speed ≤ 324.1 km/h (175 kt)	
125	Reserved	
126	Reserved	
127	Reserved	

A.1.4.3.2 Ground Track (true)

A.1.4.3.2.1 Ground Track Status

This one bit field shall define the validity of the ground track value. Coding for this field shall be as follows: 0=not valid and 1= valid.

A.1.4.3.2.2 Ground Track Value

This 7-bit (14-20) field shall define the direction (in degrees clockwise from true north) of aircraft motion on the surface. The ground track shall be encoded as an unsigned angular weighted binary numeral, with an MSB of 180 degrees and an LSB of 360/128 degrees, with ZERO (0) indicating true north. The data in the field shall be rounded to the nearest multiple of 360/128 degrees.

A.1.4.3.3 Compact Position Reporting (CPR) Format (F)

The one-bit (22) CPR format field for the surface position message shall be encoded as specified for the airborne message. That is, F = 0 shall denote an “**even**” format coding, while F = 1 shall denote an “**odd**” format coding (A.1.7.7).

A.1.4.3.4 Time Synchronization (T)

This one-bit field (21) shall indicate whether or not the time of applicability of the message is synchronized with UTC time. T equal to ZERO (0) shall denote that the time is not synchronized to UTC. T equal to ONE (1) shall denote that time of applicability is synchronized to UTC time. Synchronization shall only be used for surface position messages having the top two horizontal position precision categories (Type Codes 5 and 6).

When T=1, the time of validity in the airborne message format shall be encoded in the 1-bit F field which (in addition to CPR format type) shall indicate the 0.2

second time tick for UTC time of position validity. The F bit shall alternate between 0 and 1 for successive 0.2 second time ticks, beginning with F=0 when the time of applicability is an exact even-numbered UTC second.

A.1.4.3.5 Latitude/longitude

The latitude/longitude field in the surface message shall be a 34-bit field containing the latitude and longitude coding of the aircraft's surface position. The latitude (*Y*) and longitude (*X*) shall each occupy 17 bits. The surface latitude and longitude encoding shall contain surface CPR-encoded values in accordance with A.1.7. The unambiguous range for local decoding of surface messages shall be 166.5 km (90 NM). The positional accuracy maintained by the surface CPR encoding shall be approximately 1.25 meters.

Note: *The latitude/longitude encoding is also a function of the CPR format value (the "F" bit) described above.*

A.1.4.3.5.1 Extrapolating Position (When T=1)

This extrapolation shall conform to paragraph A.1.4.2.3.1 (Substitute "surface" for "airborne" where appropriate).

A.1.4.3.5.2 Extrapolating Position (When T=0)

This extrapolation shall conform to paragraph A.1.4.2.3.2 (Substitute "surface" for "airborne" where appropriate).

A.1.4.3.5.3 Time-Out When New Position Data is Unavailable

This time-out shall conform to paragraph A.1.4.2.3.3 (Substitute "surface" for "airborne" where appropriate).

A.1.4.4 Identification and Category Format

The identification and category squitter shall be formatted as specified in the definition of register 0,8.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.4.1 Aircraft Identification Coding

Note: *The coding of aircraft identification is defined in section 2.2.17.1.13 of RTCA/DO-181B. It is reproduced here for convenience.*

Each character shall be coded as a six-bit subset of the ICAO 7-unit coded character set (ICAO Annex 10, Vol. IV, Section 3.1.2.10, Table 3-6) as specified in the Table A-4. The character set shall be transmitted with the most significant bit (MSB) first. The reported aircraft code shall begin with character 1. Characters shall be coded consecutively without an intervening SPACE code.

Any unused character spaces at the end of the subfield shall contain a SPACE character code.

Table A-4: Aircraft Identification Character Coding

				b_6	0	0	1	1
				b_5	0	1	0	1
b_4	b_3	b_2	b_1					
0	0	0	0			P	SP[1]	0
0	0	0	1		A	Q		1
0	0	1	0		B	R		2
0	0	1	1		C	S		3
0	1	0	0		D	T		4
0	1	0	1		E	U		5
0	1	1	0		F	V		6
0	1	1	1		G	W		7
1	0	0	0		H	X		8
1	0	0	1		I	Y		9
1	0	1	0		J	Z		
1	0	1	1		K			
1	1	0	0		L			
1	1	0	1		M			
1	1	1	0		N			
1	1	1	1		O			

[1]SP = SPACE code

A.1.4.5 Airborne Velocity Format

The airborne velocity squitter shall be formatted as specified in the definition of register 0,9.

Notes:

1. *Additional details are specified in the following paragraphs.*

2. *Transmission of this format type will be discontinued by the transponder if register 0,9 is not updated for 60 seconds (A.1.5.3).*

A.1.4.5.1 Subtypes 1 and 2

Subtypes 1 and 2 of the airborne velocity format shall be used when the transmitting aircraft's velocity over ground is known. Subtype 1 shall be used for velocities under 1000 knots and subtype 2 shall be used for aircraft capable of supersonic flight when the velocity might exceed 1022 knots.

This message shall not be broadcast if the only valid data is the Intent Change and the IFR Capability flags (A.1.4.5.3, A.1.4.5.4). After initialization, broadcast shall be suppressed by loading register 0,9 with all zeros and then discontinuing updating the register until data input is available again.

The supersonic version of the velocity coding shall be used if either the east-west OR north-south velocities exceed 1022 kt. A switch to the normal velocity coding shall be made if both the east-west AND north-south velocities drop below 1000 kt.

A.1.4.5.2 Subtypes 3 and 4

Subtypes 3 and 4 of the airborne velocity format shall be used when the transmitting aircraft's velocity over ground is not known. These subtypes shall substitute airspeed and heading for the velocity over ground. Subtype 3 shall be used at subsonic velocities, while subtype 4 shall be reserved for airspeeds in excess of 1000 knots.

This message shall not be broadcast if the only valid data is the Intent Change and the IFR Capability flags (A.1.4.5.3, A.1.4.5.4). After initialization, broadcast shall be suppressed by loading register 0,9 with all zeros and then discontinuing updating the register until data input is available again.

The supersonic version of the velocity coding shall be used if the airspeed exceeds 1022 kt. A switch to the normal velocity coding shall be made if the airspeed drops below 1000 kt.

A.1.4.5.3 Intent change Flag in Airborne Velocity messages

An intent change event shall be triggered 4 seconds after the detection of new information being inserted in registers 4,0 to 4,2. The code shall remain set for 18 ± 1 seconds following an intent change.

Intent Change Flag coding:

0 = no change in intent
1 = intent change

Notes:

1. *Register 4,3 is not included since it contains dynamic data which will be continuously changing.*

2. *A four-second delay is required to provide for settling time for intent data derived from manually set devices.*

A.1.4.5.4 IFR Capability Flag (IFR) in Airborne Velocity messages

The IFR Capability Flag shall be a one-bit (bit 10) subfield in the subtype 1, 2, 3 and 4 airborne velocity messages. IFR = 1 shall signify that the transmitting aircraft has a capability for applications requiring ADS-B equipage class A1 or above. Otherwise, IFR shall be set to 0.

A.1.4.5.5 Magnetic Heading in Airborne Velocity messages

A.1.4.5.5.1 Magnetic Heading Status

This one bit field shall define the availability of the magnetic heading value. Coding for this field shall be: 0 = not available and 1 = available.

A.1.4.5.5.2 Magnetic Heading Value

This 10-bit field shall give the aircraft magnetic heading (in degrees clockwise from magnetic north) when velocity over ground is not available. The magnetic heading shall be encoded as an unsigned angular weighted binary numeral with an MSB of 180 degrees and an LSB of 360/1024 degrees, with ZERO (0) indicating magnetic north. The data in the field shall be rounded to the nearest multiple of 360/1024 degrees.

A.1.4.5.6 Difference from Baro Altitude in Airborne Velocity messages

This 8-bit field shall give the signed difference between barometric and GNSS altitude. (Coding for this field shall be as indicated in Fig A.8-6 and A.8-7).

Note: *The difference between baro altitude and GNSS height above ellipsoid (HAE) is preferred. However, GNSS altitude (MSL) may be used when airborne position is being reported using Format Type Codes 11 through 18.*

If airborne position is being reported using Format Type Codes 9 or 10, only GNSS HAE shall be used. For Format Type Codes 9 or 10, if GNSS HAE is not available, the field shall be coded with all zeros. The basis for the baro altitude difference (either GNSS HAE or altitude MSL) shall be used consistently for the reported difference.

A.1.4.6 Status Register Format

The status register shall be formatted as specified in the definition of register 0,7.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.6.1 Purpose

Note: *Unlike the other extended squitter registers, the contents of this register are not broadcast. The purpose of this register is to serve as an interface between the transponder function and the General Formatter/Manager function (GFM, A.1.6). The two fields defined for this format are the Transmission Rate Subfield and the Altitude Type Subfield.*

A.1.4.6.2 Transmission Rate Subfield (TRS)

This field shall only be used for a transponder implementation of extended squitter.

The TRS shall be used to notify the transponder of the aircraft motion status while on the surface. If the aircraft is moving, the surface position squitter shall be broadcast at a rate of twice per second, and identity squitters at a rate of once per 5 seconds. If the aircraft is stationary, the surface position squitter shall be broadcast at a rate of once per 5 seconds and the identity squitter at a rate of once per 10 seconds.

The algorithm specified in the definition of register 0,7 shall be used by the GFM (A.1.6) to determine motion status and the appropriate code shall be set in the TRS subfield. The transponder shall examine the TRS subfield to determine which rate to use when it is broadcasting surface squitters.

A.1.4.6.3 Altitude Type Subfield (ATS)

This field shall only be used for a transponder implementation of extended squitter.

Note: *The transponder normally loads the altitude field of the airborne position squitter from the same digital source as used for addressed replies. This is done to minimize the possibility that the altitude in the squitter is different from the altitude that would be obtained by direct interrogation.*

If the GFM (A.1.6) inserts GNSS height (HAE) into the airborne position squitter, it shall instruct the transponder not to insert the baro altitude into the altitude field. The ATS subfield shall be used for this purpose.

A.1.4.7 Event Driven Protocol

The event driven protocol shall operate as specified in the definition of register 0,A.

Note: *Additional details are specified in A.1.6.4 and in the following paragraphs.*

A.1.4.7.1 Purpose

Note: *The event driven protocol is intended as a flexible means to support the broadcast of messages beyond those defined for position, velocity, and identification. These typically will be messages that are broadcast regularly for a period of time based on the occurrence of an event. An example is the broadcast of emergency/priority status every second during a declared aircraft emergency. A second example is the periodic broadcast of intent information for the duration of the operational condition.*

A.1.4.7.2 Format Type Structure

Note: *As indicated in A.1.4.1, four Format Type Codes are currently assigned for messages that are delivered using the event driven protocol. These are defined for aircraft intent, aircraft state and aircraft status. Each of* *these format types has provision for a 3-bit subtype field that permits the definition of 8 different formats for each format type, or a total of 24 formats for the three assigned Format Type Codes. Additional reserved Format Type Codes in the range of 24-27 can be assigned for event driven protocol messages if growth capability becomes necessary.*

A.1.4.8 Emergency/Priority Status

The emergency/priority status squitter shall be formatted as specified in the definition of register 6,1.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.8.1 Transmission Rate

This message shall be broadcast once per second for the duration of the emergency.

A.1.4.8.2 Message Delivery

Message delivery shall be accomplished using the event driven protocol (A.1.4.7). The broadcast of this message shall takes priority over the event driven protocol broadcast of all other message types, as specified in A.1.6.4.3.

A.1.4.9 Current/Next Trajectory Change Point (TCP, TCP+1)

The current/next trajectory change point (TCP) squitter shall be formatted as specified in the definition of registers 6,2 and 6,3.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.9.1 Transmission Rate

This message shall be broadcast once per 1.7 seconds for the duration of the operation.

A.1.4.9.2 Message Delivery

Message delivery shall be accomplished using the event driven protocol (A.1.4.7).

A.1.4.9.3 Trajectory Point/Leg Type

This 4-bit (7-10) subfield shall be used to identify the type of TCP for which data is being provided in the message. Encoding of the TCP type shall be defined as shown in Table A-5.

Table A-5: TCP Type Encoding

ENCODING	MEANING
0000	No Specific Trajectory Change Point Description Information
0001	"Straight" (geodesic) Course to a "Fly By" Waypoint
0010	"Straight" (geodesic) Course to a "Fly Over" Waypoint
0011	"Straight" (geodesic) Course to a "Speed Change" Waypoint
0100	"Straight" (geodesic) Course to a "Vertical Speed Change " Waypoint
0101	Arc Course to a "Fly By" Waypoint
0110	Arc Course to a "Fly Over" Waypoint
0111	Arc Course to a "Speed Change" Waypoint
1000	Arc Course to a "Vertical Speed Change" Waypoint
1001	Holding Pattern to a Holding Fix
1010	Course FROM the Waypoint, Termination Point Unknown
1011	Reserved for future use
1100	Reserved for future use
1101	Reserved for future use
1110	Reserved for future use
1111	Reserved for future use

If the trajectory point / leg can be classified in more than one of the categories identified in Table A-5, then the type having the largest encoded value shall be used.

A.1.4.9.4 TCP Data Valid

This one bit (11) subfield shall be used to indicate the validity of the TCP, TCP+1 message. A value of ONE shall indicate a valid message. A value of ZERO shall indicate an invalid message.

A.1.4.9.5 TCP Format

This one-bit (12) subfield shall indicate whether the TCP is specified as position and time (4D), or position only (3D). A value of ZERO shall indicate a 4D TCP. A value of ONE shall indicate a 3D TCP.

The (3D) TCP format shall be used if the distance to the TCP is greater than 160 NM from the current position of the aircraft transmitting the TCP / TCP + 1.

A.1.4.9.6 TCP / TCP + 1 Altitude

This 10-bit subfield (13-22) shall be used to provide the binary encoded altitude of the current TCP or TCP+1 message. The altitude subfield shall be encoded as shown in Table A-6.

Table A-6: Altitude Subfield Encoding

TCP / TCP + 1 ALTITUDE		
Coding (binary)	**Coding** (decimal)	**Meaning** (TCP Altitude in feet)
00 0000 0000	0	No TCP Altitude information available
00 0000 0001	1	TCP Altitude is ZERO
00 0000 0010	2	TCP Altitude = 128 feet
00 0000 0011	3	TCP Altitude = 256 feet
***	***	***
11 1111 1110	1022	TCP Altitude = 130,688 feet
11 1111 1111	1023	TCP Altitude > 130,752 feet

A.1.4.9.7 TCP / TCP + 1 Latitude

A.1.4.9.7.1 4D TCP Latitude

This 14-bit (23-36) subfield shall be used to provide the airborne CPR encoded latitude for the TCP or TCP + 1 message.

The 4D TCP or TCP + 1 latitude data shall be encoded in accordance with section A.1.7.3.

A.1.4.9.7.2 3D TCP Latitude

This 17-bit (23-39) subfield shall be used to provide the angular weighted binary encoded latitude for the 3D TCP or TCP+1 message. The latitude is encoded as a 17-bit two's complement signed binary numeral in which the LSB (bit 39) has a weight of 2^{-17} times 360 degrees. North latitudes shall have positive sign, and south latitudes shall have negative sign.

A.1.4.9.8 TCP / TCP + 1 Longitude

A.1.4.9.8.1 4D TCP Longitude

This 14-bit (37-50) subfield shall be used to provide the airborne CPR encoded longitude for the 4D TCP or TCP+1 message.

Encoding of the 4D TCP / TCP + 1 longitude data shall be accomplished as defined in A.1.7.3.

A.1.4.9.8.2 3D TCP Longitude

This 17-bit (40-56) subfield shall be used to provide the angular weighted binary encoded longitude for the 3D TCP or TCP+1 message. The field is encoded as a 17-bit two's complement signed binary numeral, in which the LSB (bit 56) has a weight of 2^{-17} times 360 degrees. The prime (Greenwich) meridian is defined as zero longitude, with longitudes to the east of Greenwich being positive, and those to the west of Greenwich being negative.

A.1.4.9.9 TCP / TCP + 1 Time -to- Go (TTG)

This 6-bit (51-56) subfield shall be used to provide the binary encoded time -to-go to the TCP or TCP+1 message. The TCP Time -to- Go subfield shall be encoded as shown in Table A-7.

Table A-7 : Time-to-Go Encoding

TCP / TCP + 1 Time -to- Go (TTG)		
Coding (binary)	Coding (decimal)	Meaning (TCP / TCP + 1 Time -to- Go in minutes)
00 0000	0	No TCP Time -to- Go information available
00 0001	1	TCP Time -to- Go is ZERO
00 0010	2	TCP Time -to- Go = 0.25 minutes
00 0011	3	TCP Time -to- Go = 0.50 minutes
***	***	***
11 1110	62	TCP Time -to- Go = 15.25 minutes
11 1111	63	TCP Time -to- Go > 15.375 minutes

A.1.4.10 Aircraft Operational Coordination Message

The aircraft operational coordination message squitter shall be formatted as specified in the definition of register 6,4.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.10.1 Transmission Rate

This message shall be broadcast once per 5 seconds for the duration of the operation, except that it shall be broadcast once per 2 seconds for 30 seconds when the message content changes.

A.1.4.10.2 Message Delivery

Message delivery shall be accomplished using the event driven protocol (A.1.4.7).

A.1.4.10.3 Paired Address

This 24-bit (9-32) subfield shall be used to provide the ICAO 24-bit address of the aircraft that the ADS-B transmitting aircraft is paired with when participating in coordinated operations with another aircraft.

A.1.4.10.4 Runway Threshold Speed

This 5-bit subfield (33-37) shall be used to provide the runway threshold speed of the aircraft. Encoding of the subfield shall be as shown in Table A-8.

Table A-8 : Runway Threshold Speed Encoding

RUNWAY THRESHOLD SPEED		
Coding (binary)	**Coding** (decimal)	**Meaning** (Runway Threshold Speed in knots)
0 0000	0	No Runway Threshold Speed information available
0 0001	1	Runway Threshold Speed < 100 knots
0 0010	2	Runway Threshold Speed = 100 knots
0 0011	3	Runway Threshold Speed = 105 knots
0 0100	4	Runway Threshold Speed = 110 knots
***	***	***
1 1110	30	Runway Threshold Speed = 240 knots
1 1111	31	Runway Threshold Speed > 242.5 knots

Note: *The encoding shown in Table A-8 represents **positive magnitude data only**.*

A.1.4.10.5 Roll Angle Sign

This one-bit (38) subfield shall be used to provide the direction or sign of the roll angle of the aircraft. Encoding of the subfield shall be as shown in Table A-9.

Table A-9: Roll Angle Sign Encoding

ROLL ANGLE SIGN BIT	
Coding	**Meaning**
0	Roll Angle is +, i.e., Right Wing Down
1	Roll Angle is -, i.e., Left Wing Down

A.1.4.10.6 Roll Angle

This 5-bit subfield (39-43) shall be used to provide the roll angle of the aircraft. Encoding of the subfield shall be as shown in Table A-10.

Table A-10: Roll Angle Encoding

ROLL ANGLE		
Coding (binary)	**Coding** (decimal)	**Meaning** (Roll Angle in degrees)
0 0000	0	No Roll Angle information available
0 0001	1	Roll Angle is ZERO
0 0010	2	Roll Angle =1.0 degree
0 0011	3	Roll Angle = 2.0 degrees
***	***	***
1 1110	30	Roll Angle = 29.0 degrees
1 1111	31	Roll Angle > 29.5degrees

Note: *The encoding shown in Table A-10 represents **positive magnitude data only**. Direction is given completely by the roll angle sign bit.*

A.1.4.10.7 Go Around

This two-bit (44-45) subfield shall be used to indicate the condition when the aircraft is executing a go around. Encoding of the subfield shall be as shown in Table A-11.

Table A-11: Go Around Encoding

GO AROUND SUBFIELD	
Coding	**Meaning**
0	No information
1	Aircraft IS NOT executing a “Go Around”
2	Aircraft IS executing a “Go Around”
3	Reserved

A.1.4.10.8 Engine Out

This two-bit (46-47) subfield shall be used to indicate an engine out condition on the aircraft. Encoding of the subfield shall be as shown in Table A-12.

Table A-12: Engine Out Encoding

ENGINE OUT SUBFIELD	
Coding	**Meaning**
0	No information
1	Aircraft IS NOT experiencing an Engine Out condition
2	Aircraft IS experiencing an Engine Out condition
3	Reserved

A.1.4.11 Aircraft Operational Status

The aircraft operational status message squitter shall be formatted as specified in the definition of register 6,5.

Note: *Additional details are specified in the following paragraphs.*

A.1.4.11.1 Transmission Rate

This message shall be broadcast once per 1.7 seconds for the duration of the operation.

A.1.4.11.2 Message Delivery

Message delivery shall be accomplished using the event driven protocol (A.1.4.7).

A.1.4.11.3 En Route Operational Capabilities (CC-4)

This 4-bit (9-12) subfield shall be used to indicate en route operational capabilities of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-13.

Table A-13: En Route Operational Capabilities Encoding

CC-4 ENCODING: EN ROUTE OPERATIONAL CAPABILITIES		
CC-4 CODING		
Bit 9,10	Bit 11,12	MEANING
0 0	**0 0**	*Reserved*
	0 1	*Reserved*
	1 0	*Reserved*
	1 1	*Reserved*
0 1	**0 0**	*TCAS not Operational; CDTI not Operational or unknown*
	0 1	*TCAS not Operational; CDTI Operational*
	1 0	*TCAS Operational; CDTI not Operational or unknown*
	1 1	*TCAS Operational; CDTI Operational*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

Note: *In Table A-13 "TCAS Operational" is meant to represent TCAS II (ACAS) operating in TA/RA mode. Coding for Bits 9 and 10 set to binary 00 are unused in the DO-260A version of these requirements.*

A.1.4.11.4 Terminal Area Operational Capabilities (CC-3)

This 4-bit (13-16) subfield shall be used to indicate terminal area operational capabilities of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-14.

Table A-14: Terminal Area Operational Capabilities Encoding

CC-3 ENCODING: TERMINAL AREA OPERATIONAL CAPABILITIES		
CC-3 CODING		
Bit 13,14	Bit 15,16	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.5 Approach and Landing Operational Capabilities (CC-2)

This 4-bit (17-20) subfield shall be used to indicate approach/landing operational capabilities of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-15.

Table A-15: Approach and Landing Operational Capabilities Encoding

CC-2 ENCODING: APPROACH / LANDING OPERATIONAL CAPABILITIES		
CC-2 CODING		
Bit 17, 18	Bit 19, 20	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.6 Surface Operational Capabilities (CC-1)

This 4-bit (21-24) subfield shall be used to indicate surface operational capabilities of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-16.

Table A-16 : Surface Operational Capabilities Encoding

CC-1 ENCODING: SURFACE OPERATIONAL CAPABILITIES		
CC-1 CODING		
Bit 21, 22	Bit 23, 24	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.7 En Route Operational Capability Status (OM –4)

This 4-bit (25-28) subfield shall be used to indicate the en route operational capability status of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-17.

Table A-17: En Route Operational Capability Status Encoding

OM-4 ENCODING: EN ROUTE OPERATIONAL CAPABILITY STATUS		
OM-4 CODING		
Bit 25, 26	Bit 27, 28	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.8 Terminal Area Operational Capability Status (OM-3)

This 4-bit (29-32) subfield shall be used to indicate the terminal area operational capability status of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-18.

Table A-18: Terminal Area Operational Capability Status Encoding

OM-3 ENCODING: TERMINAL AREA OPERATIONAL CAPABILITY STATUS		
OM-3 CODING		
Bit 29, 30	Bit 31, 32	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.9 Approach/Landing Operational Capability Status (OM-2)

This 4-bit (33-36) subfield shall be used to indicate the approach and landing operational capability status of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-19.

Table A-19: Approach/Landing Operational Capability Status Encoding

OM-2 ENCODING: APPROACH/LANDING OPERATIONAL CAPABILITY STATUS		
OM-2 CODING		
Bit 33, 34	Bit 35, 36	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.10 Surface Operational Capability Status (OM-1)

This 4-bit (37-40) subfield shall be used to indicate the surface operational capability status of the ADS-B transmitting system to other aircraft as specified by the following encoding shown in Table A-20.

Table A-20: Surface Operational Capability Status Encoding

OM-1 ENCODING: SURFACE OPERATIONAL CAPABILITY STATUS		
OM_1 CODING		
Bit 37, 38	Bit 39, 40	MEANING
0 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
0 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 0	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*
1 1	**0 0**	*TBD*
	0 1	*TBD*
	1 0	*TBD*
	1 1	*TBD*

A.1.4.11.11 Version Number (VN)

This 3-bit (41-43) subfield shall be used to indicate the Version Number of the formats and protocols in use on the aircraft installation. Encoding of the subfield shall be as shown in Table A-21.

Table A-21: Version Number Encoding

VERSION NUMBER SUBFIELD	
Coding	Meaning
000	Conformant to DO-260
001	Conformant to DO-260A
010 – 111	Reserved

A.1.4.12 Additional Identification and Category Transmission

The aircraft identification and category squitter shall be formatted as specified in the definition of register 0,8.

Note: *It is automatically broadcast by the transponder or non-transponder device every 5 seconds as part of the basic ADS-B message broadcast.*

During operations that utilize TCP, TCP+1 and Aircraft Operational Status messages, the Identification and Category message shall also be transmitted via the event driven protocol in order to improve detection of this message in high interference environments.

A.1.4.12.1 Transmission Rate

This message shall be broadcast once per 5 seconds for the duration of the operation.

A.1.4.12.2 Message Delivery

Message delivery shall be accomplished using the event driven protocol (A.1.4.7).

A.1.5 Initialization and Timeout

Note: *Initialization and timeout functions for extended squitter broadcast are performed by the transponder and are specified in DO-181B. A description of these functions is presented in the following paragraphs to serve as reference material for the section on the GFM (A.1.6).*

A.1.5.1 Initiation of Extended Squitter Broadcast

At power up initialization, the transponder shall commence operation in a mode in which it broadcasts only acquisition squitters. The transponder shall initiate the broadcast of extended squitters for airborne position, surface position, airborne velocity and aircraft identification when data are inserted into registers 0,5, 0,6, 0,9 and 0,8 respectively. This determination shall be made individually for each squitter type. The insertion of altitude or surveillance status data into register 0,5 by the transponder shall not satisfy the minimum requirement for broadcast of the airborne position squitter.

Note: *This suppresses the transmission of extended squitters from aircraft that are unable to report position, velocity or identity information.*

A.1.5.2 Register Timeout

The transponder shall clear all but the altitude and surveillance status subfields in the airborne position register (register 0,5) and all 56-bits of the surface position, squitter status and airborne velocity registers (registers 0,6, 0,7 and 0,9), if these registers are not updated within two seconds of the previous update. This timeout shall be determined separately for each of these registers. The insertion of altitude or surveillance status data by the transponder into these registers shall not qualify as a register update for the purposes of this timeout condition. Transponder data insertion shall not be affected by a register timeout condition.

Notes:

1. *These registers are cleared to prevent the reporting of outdated position, velocity and squitter rate information.*

2. *The identification register, 0,8, is not cleared since it contains data that rarely changes in flight and is less frequently updated. The event-driven register, 0,A or equivalent transmit register does not need to be cleared since its contents are only broadcast once each time that the register is loaded (A.1.6.4).*

3. *During a register timeout event, the ME field of the extended squitter may contain all ZEROs, except for any data inserted by the transponder.*

A.1.5.3 Termination of Extended Squitter Broadcast

If input to the register for a squitter type stops for 60 seconds, broadcast of that extended squitter type shall be discontinued until data insertion is resumed. The insertion of altitude by the transponder shall satisfy the minimum requirement for continuing to broadcast the airborne position squitter.

Notes:

1. *Until timeout, a squitter type may contain an ME field of all ZEROs.*

2. *Continued transmission for 60 seconds is required so that receiving aircraft will know that the data source for the message has been lost.*

A.1.5.4 Requirements for Non-Transponder Devices

Non-transponder devices shall provide the same functionality for initialization, register timeout and broadcast termination as specified for the transponder case in A.1.5.1 to A.1.5.3.

A.1.6 General Formatter/Manager (GFM)

Note: *The General Formatter/Manager (GFM) is the name that will be used to refer to the function that formats messages for insertion in the extended squitter registers. In addition to data formatting, there are other tasks that have to be performed by this function.*

A.1.6.1 Navigation Source Selection

The GFM shall be responsible for the selection of the default source for aircraft position and velocity, the commanded altitude source, and for the reporting of the associated position and altitude errors.

A.1.6.2 Loss of Input Data

The GFM shall be responsible for loading the registers for which it is programmed at the required update rate. If for any reason data is unavailable for a time equal to twice the update interval or 2 seconds (whichever is greater), the GFM shall ZERO old data (on a per field basis) and insert the resulting message into the appropriate register.

Note: *For register 0,5 and 0,6 a loss of position data would cause the GFM to set the Format Type Code to ZERO as the means of indicating "no position data" since all ZEROs in the Lat/Lon fields is a legal value.*

A.1.6.3 Special Processing for Format Type Code Zero

A.1.6.3.1 Significance of Format Type Code Equal to Zero

Notes:

1. *Format Type Code ZERO (0) is labeled "no position information." This is intended to be used when the lat/lon information is not available or invalid, and still permit the reporting of baro altitude loaded by the transponder. The principal use of this message case is to provide ACAS the ability to passively receive altitude.*

2. *Special handling is required for the airborne and surface position messages because a CPR encoded value of all ZEROs in the lat/lon field is a valid value.*

A.1.6.3.2 Broadcast of Format Type Code Equal to Zero

Format Type Code 0 shall only be set by the following events:

1. An extended squitter register monitored by the transponder (register 0,5, 0,6, 0,7 and 0,9) has not been loaded by the GFM for 2 seconds. In this case the transponder clears the entire 56 bits of the register that timed out. (In the case of the airborne position register, the altitude subfield is only ZEROed if no altitude data is available). Transmission of the extended squitter that broadcasts the timed out register will itself stop in 60 seconds. Broadcast of this extended squitter will resume when the GFM begins to insert data into the register.

2. The GFM determines that all navigation sources that can be used for the extended squitter airborne or surface position message are either missing or invalid. In this case the GFM can clear the Format Type Code and all other fields of the airborne position, surface position, or airborne velocity message and insert this zeroed message in the appropriate register. This should only be done once so that the transponder can detect the loss of data insertion and suppress the broadcast of the related squitter.

Note that in all of the above cases, a Format Type Code of ZERO contains a message of all ZEROs. The only exception is the airborne position format that may contain barometric altitude and surveillance status data as set by the transponder. There is no analogous case for the other extended squitter format types, since a zero value in any of the fields indicates no information.

A.1.6.3.3 Reception of Format Type Code Equal to Zero

If a squitter with format Type Code equal to ZERO (0) is received, it shall be checked to see if altitude is present. If altitude is not present, the message shall be discarded. If altitude is present, it may be used to update altitude. An extended squitter containing Format Type Code ZERO shall only be used to update the altitude of an aircraft already in track.

Note: *For ACAS, this could be an aircraft that was being maintained via hybrid surveillance when the position data input failed. In this case, altitude only could be used for a short period of time. Interrogation would have to begin at the update rate for that track to ensure update of range and bearing information on the display.*

A.1.6.4 Handling of Event Driven Protocol

The event-driven interface protocol shall provide a general-purpose interface into the transponder function for messages beyond those that are regularly transmitted all the time (provided input data is available). This protocol shall operate by having the transponder broadcast a message once each time the event driven register is loaded by the GFM.

Note: *This gives the GFM complete freedom in setting the update rate (up to a maximum) and duration of broadcast for applications such as emergency status and intent reporting.*

In addition to formatting, the GFM shall control the timing of message insertion so that it provides the necessary pseudo-random timing variation and does not exceed the maximum transponder broadcast rate for the event driven protocol.

A.1.6.4.1 Transponder Support for the Event Driven Protocol

A message shall be transmitted once by the transponder, each time that register 0,A is loaded. Transmission shall be delayed if the transponder is busy at the time of insertion.

Note: *Delay times are short, a maximum of several milliseconds for the longest transponder transaction.*

The maximum transmission rate for the event-driven protocol shall limited by the transponder to twice per second. If a message is inserted in the event-driven register and cannot be transmitted due to rate limiting, it shall be held and transmitted when the rate limiting condition has cleared. If a new message is received before transmission is permitted, it shall overwrite the earlier message.

Note: *The squitter transmission rate and the duration of squitter transmissions is application dependent. Choices made should be the minimum rate and duration consistent with the needs of the application.*

A.1.6.4.2 GFM Use of the Event Driven Protocol

Note: *More than one application at a time may be supported by the event-driven protocol. The GFM handles requests for broadcast by these applications and is the only function that is capable of inserting data into register 0,A. In this way, the GFM can provide the pseudo random timing for all applications using this protocol and maintain a maximum insertion rate that does not exceed the transponder imposed limit.*

An application that wants to use the event driven protocol shall notify the GFM of the format type and required update rate. The GFM shall then locate the necessary input data for this format type and begin inserting data into register 0,A at the required rate. The GFM shall also insert this message into the register for this format type. This register image shall be maintained to allow readout of this information by air-ground or air-air register readout. When broadcast of a format type ceases, the GFM shall clear the corresponding register assigned to this message.

The maximum rate that can be supported by the event driven protocol shall be twice per second from one or a collection of applications. For each event-driven format type being broadcast, the GFM shall retain the time of the last insertion into register 0,A. The next insertion shall be scheduled at a random interval that is uniformly distributed over the range of the update interval ± 0.1 second relative to the previous insertion into register 0,A for this format type.

The GFM shall monitor the number of insertions scheduled in any one second interval. If more than two would occur, the GFM shall add a delay as necessary to ensure that the limit of two messages per second is observed.

A.1.6.4.3 Event Driven Protocol Message Priority

If the event-driven message transmission rate must be reduced in order not to exceed the maximum rate specified in A.1.6.4.1, transmission priority shall be assigned as follows:

1. If the Emergency/Priority Status Message (A.1.4.8) is active, it shall continue to be transmitted at the specified rate of once per second. Other active event-driven messages shall be assigned equal priority for the remaining capacity.

2. If the Emergency/Priority Status Message is not active, transmission priority shall be allocated equally to all active event-driven messages.

A.1.7 Latitude/Longitude Coding Using Compact Position Reporting (CPR)

A.1.7.1 Principle of the CPR algorithm

Notes:

1. *The Mode S Extended Squitters use Compact Position Reporting (CPR) to encode latitude and longitude efficiently into messages. The resulting*

messages are compact in the sense that several higher-order bits, which are normally constant for long periods of time, are not transmitted in every message. For example, in a direct binary representation of latitude, one bit would designate whether the aircraft is in the northern or southern hemisphere. This bit would remain constant for a long time, possibly the entire life of the aircraft. To repeatedly transmit this bit in every position message would be inefficient.

2. *Because the higher-order bits are not transmitted, it follows that multiple locations on the earth will produce the same encoded position. If only a single position message were received, the decoding would involve ambiguity as to which of the multiple solutions is the correct location of the aircraft. The CPR technique includes a provision to enable a receiving system to unambiguously determine the location of the aircraft. This is done by encoding in two ways that differ slightly. The two formats, called even-format and odd-format, are each transmitted fifty percent of the time. Upon reception of both types within a short period (approximately 10 seconds), the receiving system can unambiguously determine the location of the aircraft.*

3. *Once this process has been carried out, the higher-order bits are known at the receiving station, so subsequent single message receptions serve to unambiguously indicate the location of the aircraft as it moves.*

4. *In certain special cases, a single reception can be decoded into the correct location without an even/odd pair. This decoding is based on the fact that the multiple locations are spaced by at least 360 NM. In addition to the correct locations, the other locations are separated by integer multiples of 360 NM to the north and south and also integer multiples of 360 NM to the east and west. In a special case in which it is known that reception is impossible beyond a range of 180 NM, the nearest solution is the correct location of the aircraft.*

5. *The parameter values in the preceding paragraph (360 and 180 NM) apply to the airborne CPR encoding. For aircraft on the surface, the CPR parameters are smaller by a factor of 4. This encoding yields better resolution but reduces the spacing of the multiple solutions.*

A.1.7.2 CPR Algorithm Parameters and Internal Functions

The CPR algorithm shall utilize the following parameters whose values are set as follows for the Mode S extended squitter application:

1. The number of bits used to encode a position coordinate, *Nb*, is set as follows:

   For airborne encoding: *Nb* = 17

   For surface encoding: *Nb* = 19

   For TCP, TCP+1 encoding: *Nb* = 14.

Note 1: *The* Nb *parameter determines the encoded position precision (approximately 5 m for the airborne encoding, 1.25 m for the surface encoding, and 41 m for the TCP, TCP+1 encoding).*

2. The number of geographic latitude zones between the equator and a pole, denoted *NZ*, is set to 15.

Note 2: *The NZ parameter determines the unambiguous airborne range for decoding (360 NM). The surface latitude/longitude encoding omits the high-order 2 bits of the 19-bit CPR encoding, so the effective unambiguous range for surface position reports is 90 NM.*

The CPR algorithm shall define internal functions to be used in the encoding and decoding processes.

a. The notation **floor**(x) denotes the floor of *x*, which is defined as the greatest integer value *k* such that *k* £ *x*.

Note 3: *For example,* ***floor****(3.8) = 3, while* ***floor****(-3.8) = -4.*

b. The notation |*x*| denotes the absolute value of *x*, which is defined as the value *x* when *x* ≥0 and the value –*x* when *x* < 0.

c. The notation **MOD**(*x*,*y*) denotes the “modulus” function, which is defined to return the value

$$\mathrm{MOD}(x,y) = x - y \cdot \mathrm{floor}\left(\frac{x}{y}\right) \text{ where } y \neq 0 .$$

Note 4: *The value y is always positive in the following CPR algorithms. When x is non-negative,* ***MOD****(x,y) is equivalent to the remainder of x divided by y. When x represents a negative angle, an alternative way to calculate* ***MOD****(x,y) is to return the remainder of (x+360°) divided by y.*

For example, $\mathrm{MOD}(-40°,6°) = \mathrm{MOD}(320°,6°) = 2°$.

d. The notation **NL**(*x*) denotes the “number of longitude zones” function of the latitude angle *x*. The value returned by **NL**(*x*) is constrained to the range from 1 to 59. **NL**(*x*) is defined for most latitudes by the equation,

$$\mathrm{NL}(lat) = \mathrm{floor}\left(2p \cdot \left[\arccos\left(1 - \frac{1-\cos\left(\frac{p}{2 \cdot NZ}\right)}{\cos^2\left(\frac{p}{180°} \cdot |lat|\right)} \right) \right]^{-1} \right),$$

where *lat* denotes the latitude argument in degrees. For latitudes at or near the N or S pole, where the above formula would either be undefined or yield **NL**(*lat*) = 0, the value returned by the NL( ) function shall be 1. Likewise, at the equator, where the above formula might otherwise yield NL(*lat*) = 60, the value returned by the NL( ) function shall be 59.

Note 5: *This equation for NL( ) is impractical for a real-time implementation. A table of transition latitudes can be pre-computed using the following equation:*

$$lat = \frac{180°}{\pi} \cdot \arccos\left(\sqrt{\frac{1 - \cos\left(\frac{\pi}{2 \cdot NZ}\right)}{1 - \cos\left(\frac{2\pi}{NL}\right)}} \right) \text{ for } NL = 2 \text{ to } 4 \cdot NZ - 1,$$

and a table search procedure used to obtain the return value for NL( ). *The table value for NL = 1 is 90 degrees.*

A.1.7.3 CPR Encoding Process

The CPR encoding process shall calculate the encoded position values XZ_i and YZ_i for either airborne, surface, or TCP, TCP+1 latitude and longitude fields from the global position *lat* (latitude in degrees), *lon* (longitude in degrees), and the CPR encoding type *i* (0 for even format and 1 for odd format), by performing the following sequence of computations. The CPR encoding for TCP, TCP+1 always uses the even format (*i* = 0), whereas the airborne and surface encoding use both even (*i* = 0) and odd (*i* = 1) formats.

a. $Dlat_i$ (the latitude zone size in the N-S direction) is computed from the equation:

$$Dlat_i = \frac{360°}{4 \cdot NZ - i}$$

b. YZ_i (the Y-coordinate within the Zone) is then computed from $Dlat_i$ and *lat* using separate equations:

For airborne encoding: $$YZ_i = \text{floor}\left(2^{17} \cdot \frac{\text{MOD}(lat, Dlat_i)}{Dlat_i} + \frac{1}{2} \right)$$

For surface encoding: $$YZ_i = \text{floor}\left(2^{19} \cdot \frac{\text{MOD}(lat, Dlat_i)}{Dlat_i} + \frac{1}{2} \right)$$

For TCP, TCP+1 encoding: $$YZ_0 = \text{floor}\left(2^{14} \cdot \frac{\text{MOD}(lat, Dlat_0)}{Dlat_0} + \frac{1}{2} \right)$$

a. $Rlat_i$ (the latitude that a receiving ADS-B system will extract from the transmitted message) is then computed from *lat*, YZ_i, and $Dlat_i$ using separate equations:

For airborne encoding: $$Rlat_i = Dlat_i \cdot \left(\frac{YZ_i}{2^{17}} + \text{floor}\left(\frac{lat}{Dlat_i} \right) \right)$$

For surface encoding: $$Rlat_i = Dlat_i \cdot \left(\frac{YZ_i}{2^{19}} + \text{floor}\left(\frac{lat}{Dlat_i} \right) \right)$$

For TCP, TCP+1 encoding: $$Rlat_0 = Dlat_0 \cdot \left(\frac{YZ_i}{2^{14}} + \text{floor}\left(\frac{lat}{Dlat_0} \right) \right)$$

a. $Dlon_i$ (the longitude zone size in the E-W direction) is then computed from $Rlat_i$ using the equation:

$$Dlon_i = \begin{cases} \dfrac{360°}{\text{NL}(Rlat_i) - i}, & \text{when NL}(Rlat_i) - i > 0 \\ 360°, & \text{when NL}(Rlat_i) - i = 0 \end{cases}$$

b. XZ_i (the X-coordinate within the Zone) is then computed from *lon* and $Dlon_i$ using separate equations:

For airborne encoding: $$XZ_i = \text{floor}\left(2^{17} \cdot \frac{\text{MOD}(lon, Dlon_i)}{Dlon_i} + \frac{1}{2} \right)$$

For surface encoding: $$XZ_i = \text{floor}\left(2^{19} \cdot \frac{\text{MOD}(lon, Dlon_i)}{Dlon_i} + \frac{1}{2} \right)$$

For TCP, TCP+1 encoding: $$XZ_0 = \text{floor}\left(2^{14} \cdot \frac{\text{MOD}(lon, Dlon_0)}{Dlon_0} + \frac{1}{2} \right)$$

a. Finally, limit the values of XZ_i and YZ_i to fit in the 17-bit or 14-bit field allotted to each coordinate:

For airborne encoding: $$YZ_i = \text{MOD}(YZ_i, 2^{17}), \quad XZ_i = \text{MOD}(XZ_i, 2^{17})$$

For surface encoding: $$YZ_i = \text{MOD}(YZ_i, 2^{17}), \quad XZ_i = \text{MOD}(XZ_i, 2^{17})$$

For TCP, TCP+1 encoding: $$YZ_0 = \text{MOD}(YZ_0, 2^{14}), \quad XZ_0 = \text{MOD}(XZ_0, 2^{14})$$

A.1.7.4 Locally Unambiguous CPR Decoding

The CPR algorithm shall decode a geographic position (latitude, $Rlat_i$, and longitude, $Rlon_i$,) that is locally unambiguous with respect to a reference point (lat_s, lon_s) known to be within 180 NM of the true airborne position (or within 45 NM for a surface message).

Note: *This reference point may be a previously tracked position that has been confirmed by global decoding (see A.1.7.7) or it may be the own aircraft position, which would be used for decoding a new tentative position report.*

The encoded position coordinates XZ_i and YZ_i and the CPR encoding type i (0 for the even encoding and 1 for the odd encoding) contained in a Mode S extended squitter message shall be decoded by performing the sequence of computations given in A.1.7.5 for the airborne and TCP, TCP+1 format types and in A.1.7.6 for the surface format type.

A.1.7.5 Computations for the Airborne Message and TCP, TCP+1 Message

The following computations shall be performed to obtain the decoded lat/lon for the airborne and TCP, TCP+1 message formats. For the TCP, TCP+1 format, i is always 0 (even encoding), whereas the airborne format uses both even (i = 0) and odd (i = 1) encoding. For the airborne format, Nb = 17, and for the TCP, TCP+1 format, Nb = 14.

a. $Dlat_i$ is computed from the equation:

$$Dlat_i = \frac{360°}{4 \cdot NZ - i}$$

b. The latitude zone index number, j, is then computed from the values of lat_s, $Dlat_i$ and YZ_i using the equation:

$$j = \text{floor}\left(\frac{lat_s}{Dlat_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lat_s, Dlat_i)}{Dlat_i} - \frac{YZ_i}{2^{Nb}}\right)$$

c. The decoded position latitude, $Rlat_i$, is then computed from the values of j, $Dlat_i$, and YZ_i using the equation:

$$Rlat_i = Dlat_i \cdot \left(j + \frac{YZ_i}{2^{Nb}}\right)$$

d. $Dlon_i$ (the longitude zone size in the E-W direction) is then computed from $Rlat_i$ using the equation:

$$Dlon_i = \begin{cases} \dfrac{360°}{\text{NL}(Rlat_i) - i}, & \text{when NL}(Rlat_i) - i > 0 \\ 360°, & \text{when NL}(Rlat_i) - i = 0 \end{cases}$$

e. The longitude zone coordinate m is then computed from the values of lon_s, $Dlon_i$, and XZ_i using the equation:

$$m = \text{floor}\left(\frac{lon_s}{Dlon_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lon_s, Dlon_i)}{Dlon_i} - \frac{XZ_i}{2^{Nb}}\right)$$

f. The decoded position longitude, $Rlon_i$, is then computed from the values of m, XZ_i, and $Dlon_i$ using the equation:

$$Rlon_i = Dlon_i \cdot \left(m + \frac{XZ_i}{2^{Nb}}\right)$$

A.1.7.6 Computations for the Surface Message

The following computations shall be performed to obtain the decoded latitude and longitude for the surface position format.

1. $Dlat_i$ is computed from the equation:

$$Dlat_i = \frac{90°}{4 \cdot NZ - i}$$

2. The latitude zone index, j, is then computed from the values of lat_s, $Dlat_i$ and YZ_i using the equation:

$$j = \text{floor}\left(\frac{lat_s}{Dlat_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lat_s, Dlat_i)}{Dlat_i} - \frac{YZ_i}{2^{17}}\right)$$

3. The decoded position latitude, $Rlat_i$, is then computed from the values of j, $Dlat_i$, and YZ_i using the equation:

$$Rlat_i = Dlat_i \cdot \left(j + \frac{YZ_i}{2^{17}}\right)$$

4. $Dlon_i$ (the longitude zone size, in the E-W direction) is then computed from $Rlat_i$ using the equation:

$$Dlon_i = \begin{cases} \dfrac{90°}{\text{NL}(Rlat_i) - i}, & \text{when NL}(Rlat_i) - i > 0 \\ 90°, & \text{when NL}(Rlat_i) - i = 0 \end{cases}$$

5. The longitude zone coordinate m is then computed from the values of lon_s, $Dlon_i$, and XZ_i using the equation:

$$m = \text{floor}\left(\frac{lon_s}{Dlon_i}\right) + \text{floor}\left(\frac{1}{2} + \frac{\text{MOD}(lon_s, Dlon_i)}{Dlon_i} - \frac{XZ_i}{2^{17}}\right)$$

6. The decoded position longitude, $Rlon_i$, is then computed from the values of m, XZ_i, and $Dlon_i$ using the equation:

$$Rlon_i = Dlon_i \cdot \left(m + \frac{XZ_i}{2^{17}}\right)$$

A.1.7.7 Globally Unambiguous Airborne Position Decoding

The CPR algorithm shall utilize one airborne-encoded "**even**" format reception (denoted XZ_0, YZ_0), together with one airborne-encoded "**odd**" format reception (denoted XZ_1, YZ_1), to regenerate the global geographic position latitude, *Rlat*, and longitude, *Rlon*. The time between the "**even**" and "**odd**" format encoded position reports shall be no longer than 10 seconds.

Note 1: *This algorithm might be used to obtain globally unambiguous position reports for aircraft out of the range of ground sensors, whose position reports are coming via satellite data links. It might also be applied to ensure that local positions are being correctly decoded over long ranges from the receiving sensor.*

Note 2: *The time difference limit of 10 seconds between the even- and odd-format position reports is determined by the maximum permitted separation of 3 NM. Positions greater than 3 NM apart cannot be used to solve for a unique global position. An aircraft capable of a speed of 1,850 km/h (1,000 kt) will fly about 5.1 km (2.8 NM) in 10 seconds. Therefore, the CPR algorithm will be able to unambiguously decode its position over a 10-second delay between position reports.*

Given a 17-bit airborne position encoded in the "**even**" format (XZ_0, YZ_0) and another encoded in the "**odd**" format (XZ_1, YZ_1), separated by no more than 10 seconds (= 3 NM), the CPR algorithm shall regenerate the geographic position from the encoded position reports by performing the following sequence of steps:

a. Compute $Dlat_0$ and $Dlat_1$ from the equation:

$$Dlat_i = \frac{360°}{4 \cdot NZ - i}$$

b. Compute the latitude index:

$$j = \text{floor}\left(\frac{59 \cdot YZ_0 - 60 \cdot YZ_1}{2^{17}} + \frac{1}{2} \right)$$

c. Compute the values of $Rlat_0$ and $Rlat_1$ using the following equation:

$$Rlat_i = Dlat_i \cdot \left(\text{MOD}(j, 60 - i) + \frac{YZ_i}{2^{17}} \right)$$

Southern hemisphere values of $Rlat_i$ will fall in the range from 270° to 360°. Subtract 360° from such values, thereby restoring $Rlat_i$ to the range from –90° to +90°.

d. If **NL**($Rlat_0$) is not equal to **NL**($Rlat_1$) then the two positions straddle a transition latitude—thus a solution for global longitude is not possible. Wait for positions where they are equal.

e. If **NL**($Rlat_0$) is equal to **NL**($Rlat_1$) then proceed with computation of $Dlon_i$, according to whether the most recently received airborne position message was encoded with the even format (i = 0) or the odd format (i = 1) :

$$Dlon_i = \frac{360°}{n_i},$$

where n_i = greater of $[\mathrm{NL}(Rlat_i) - i]$ and 1.

f. Compute m, the longitude index:

$$m = \mathrm{floor}\left(\frac{XZ_0 \cdot (NL - 1) - XZ_1 \cdot NL}{2^{17}} + \frac{1}{2} \right),$$

where $NL = \mathrm{NL}(Rlat_i)$.

g. Compute the global longitude, $Rlon_0$ or $Rlon_1$, according to whether the most recently received airborne position message was encoded using the even format (that is, with i = 0) or the odd format (i = 1):

$$Rlon_i = Dlon_i \cdot \left(\mathrm{MOD}(m, n_i) + \frac{XZ_i}{2^{17}} \right),$$

where n_i = greater of $[\mathrm{NL}(Rlat_i) - i]$ and 1.

A.1.7.8 CPR Decoding of Received Position Reports

A.1.7.8.1 Overview

Note: *The techniques described in the preceding paragraphs (locally and globally unambiguous decoding) are used together to decode the lat/lon contained in airborne, surface, and TCP or TCP+1 position reports. The process begins with globally unambiguous decoding based upon the receipt of an even and an odd encoded position squitter. Once the globally unambiguous position is determined, the emitter centered local decoding technique is used for subsequent decoding based on a single position report, either even or odd encoding.*

A.1.7.8.2 Emitter Centered Local Decoding

In this approach, the most recent position of the emitter shall be used as the basis for the local decoding.

Note: *This produces an unambiguous decoding at each update, since the transmitting aircraft cannot move more than 360 NM between position updates.*

A.1.7.8.3

A.1.8 Formats for Extended Squitter

The extended squitter messages shall be formatted as defined in the following tables.

Note: *In some cases, ARINC 429 labels are referenced for specific message fields. These references are only intended to clarify the field content, and are not intended as a requirement to use these ARINC 429 labels as the source for the message field.*

Figure A-1: Extended Squitter Airborne Position

BDS 0,5

Bits	Field
1–5	FORMAT TYPE CODE (See A.1.4.1 and Note 1)
6–7	SURVEILLANCE STATUS
8	SINGLE ANTENNA FLAG (SAF) (See A.1.4.2.5)
9–20	ALTITUDE Specified by the Format Type Code (1) the altitude code (AC) as specified in section 2.2.13.1.2 of DO-181B but with the M-bit removed (Ref ARINC 429 Label 203), or (2) GNSS height (HAE) (Ref. ARINC 429 Label 370)
21	TIME (T) (See A.1.4.2.2)
22	CPR FORMAT (F) (See A.1.4.2.1)
23–39	MSB (bit 23) ENCODED LATITUDE (CPR Airborne Format See A.1.7.1 to A.1.7.5) LSB (bit 39)
40–56	MSB (bit 40) ENCODED LONGITUDE (CPR Airborne Format See A.1.7.1 to A.1.7.4) LSB (bit 56)

Purpose: To provide accurate airborne position information

Surveillance Status coding
0 = no condition information
1 = permanent alert (emergency condition)
2 = temporary alert (change in Mode A identity code other than emergency condition)
3 = SPI condition

Codes 1 and 2 take precedence over code 3.

Note: *When horizontal position information is unavailable, but altitude information is available, the airborne position message is transmitted with a Format Type Code of ZERO in bits 1-5 and the barometric pressure altitude in bits 9 to 20. If neither horizontal position nor barometric altitude information is available, then all 56 bits of register 0,5 shall be ZEROed. The ZERO Format Type Code field indicates that latitude and longitude information is unavailable, while the ZERO altitude field indicates that altitude information is unavailable.*

Figure A-2: Extended Squitter Surface Position

BDS 0,6

Bit	Field
1	
2	
3	FORMAT TYPE CODE
4	(See A.1.4.1)
5	
6	
7	
8	
9	MOVEMENT
10	(See A.1.4.3.1)
11	
12	
13	STATUS for Gnd Tk (1 =valid, 0 = not valid)
14	MSB
15	
16	GROUND TRACK (7 bits)
17	(See A.1.4.3.2)
18	
19	**Resolution = 360/128 deg**
20	LSB
21	TIME (T) (See A.1.4.2.2)
22	CPR FORMAT (F) (See A.1.4.2.1)
23	MSB
24	
25	
26	
27	
28	
29	
30	ENCODED LATITUDE
31	
32	(CPR Surface Format
33	See A.1.7.1 to A.1.7.4 and A.1.7.6)
34	
35	
36	
37	
38	
39	LSB
40	MSB
41	
42	
43	
44	
45	
46	
47	ENCODED LONGITUDE
48	
49	(CPR Surface Format
50	See A.1.7.1 to A.1.7.4)
51	
52	
53	
54	
55	
56	LSB

Purpose: To provide accurate surface position information.

Figure A-3: Extended Squitter Status

BDS 0,7

Bit	Field
1	TRANSMISSION RATE
2	SUBFIELD (TRS)
3	ALTITUDE TYPE SUBFIELD (ATS)
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	RESERVED
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
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56	

PURPOSE : To provide information on the capability and status of the extended squitter rate of the transponder.

Transmission Rate Subfield (TRS) coding:

0 = No capability to determine surface squitter rate.
1 = High surface squitter rate selected.
2 = Low surface squitter rate selected.
3 = Reserved

Altitude type subfield (ATS) coding:

0 = barometric altitude.
1 = GNSS height (HAE), ARINC 429 Label 370

Note: *Aircraft determination of surface squitter rate. For aircraft that have the capability to automatically determine their surface squitter rate the method that must be used to switch between the high and low transmission rates is as follows:*

a) Switching from high to low rate: Aircraft must switch from high to low rate when the onboard navigation unit reports that the aircraft's position has not changed more than 10 meters in a 30 second sampling interval.

b) Switching from low to high rate: Aircraft must switch from low to high rate as soon as the aircraft's position has changed by 10 meters or more since the low rate was selected.

In all cases, the automatically selected transmission rate is subject to being overridden by commands received from ground control.

Figure A-4: Extended Squitter Identification and Category

BDS 0,8

Bits	Field
1–5	FORMAT TYPE CODE (See A.1.4.1)
6–8	AIRCRAFT CATEGORY
9 (MSB) – 14 (LSB)	CHARACTER 1
15 (MSB) – 20 (LSB)	CHARACTER 2
21 (MSB) – 26 (LSB)	CHARACTER 3
27 (MSB) – 32 (LSB)	CHARACTER 4
33 (MSB) – 38 (LSB)	CHARACTER 5
39 (MSB) – 44 (LSB)	CHARACTER 6
45 (MSB) – 50 (LSB)	CHARACTER 7
51 (MSB) – 56 (LSB)	CHARACTER 8

Purpose: To provide aircraft identification and category.

Type coding:

1 = Aircraft identification, category set D
2 = Aircraft identification, category set C
3 = Aircraft identification, category set B
4 = Aircraft identification, category set A

ADS-B Emitter Category coding:

Set A
0 = No ADS-B Emitter Category Information
1 = Light (< *15 500* lbs.)
2 = Small (*15 500* to 75 000 lbs.)
3 = Large (75 000 to 300 000 lbs.)
4 = High Vortex Large(aircraft such as B-757)
5 = Heavy (> 300 000 lbs.)
6 = High Performance (> 5 g acceleration and > 400kts)
7 = Rotorcraft

Set B
0 = No ADS-B Emitter Category Information
1 = Glider/sailplane
2 = Lighter-than-Air
3 = Parachutist/Skydiver
4 = Ultralight/hang-glider/paraglider
5 = Reserved
6 = Unmanned Aerial Vehicle
7 = Space/Trans-atmospheric vehicle

Set C
0 = No ADS-B Emitter Category Information
1 = Surface Vehicle – Emergency Vehicle
2 = Surface Vehicle – Service Vehicle
3 = Fixed Ground or Tethered Obstruction
4-7 = Reserved

Set D : Reserved

Aircraft identification coding:

Coding as specified for A.1.4.4

Figure A-5: Extended Squitter Airborne Velocity (Subtype 0: Initial Coding)

BDS 0,9

Bit	Field	
1	MSB	**1**
2		**0**
3	FORMAT TYPE CODE = 19	**0**
4		**1**
5	LSB	**1**
6	SUBTYPE CODE	0
7		0
8		**0**
9	**RESERVED**	
10	DIRECTION BIT for E-W velocity (0=East, 1=West)	
11		
12	EAST-WEST VELOCITY (1 knot resolution)	
13		
14	0 = no information	**Ref . ARINC 429 Labels**:
15	1 = 0 kt	**GPS: 174**
16	2 = 1 kt	**INS: 367**
17	3 = 2 kt	
18	-	
19	2046 = 2045 kt	
20	All ones = greater than 2045.5 kt	
21		
22	DIRECTION BIT for N-S velocity **(0=North, 1=South)**	
23		
24	NORTH-SOUTH VELOCITY (1 knot resolution)	
25		
26	0 = no information	**Ref . ARINC 429 Labels**:
27	1 = 0 kt	**GPS: 166**
28	2 = 1 kt	**INS: 366**
29	3 = 2 kt	
30	-	
31	2046 = 2045 kt	
32	All ones = greater than 2045.5 kt	
33		
34	SIGN BIT FOR TURN RATE **(0=Right, 1= Left)**	
35		
36	TURN RATE	
37	All zeros = no information	
38	All ones = greater than 15 degrees/s	
39		
40	Resolution 15/62 deg/sec	
41	SIGN BIT FOR VERTICAL RATE **(0=up, 1=down)**	
42	VERTICAL RATE (Resolution 32 ft/min)	
43		
44	0 = no information	
45	1 = 0 ft/min	
46	2 = 32 ft/min	**Ref. ARINC 429 Labels**:
47	-	**GPS: 165**
48	510 = 16288 ft/min	**INS: 365**
49	All ones = greater than 16228 ft/min	
50		
51		
52	RESERVED	
53		
54		
55		
56		

Purpose: To provide additional state information on airborne aircraft**.**

Subtype Coding

Code	Velocity	Type
0	As in first edition of Doc 968	
1	Ground speed	normal
2		supersonic
3	Airspeed, heading	normal
4		supersonic
5	Not assigned	
6	Not assigned	
7	Not assigned	

Figure A-6 : Extended Squitter Airborne Velocity (Subtypes 1 and 2: Velocity Over Ground)

BDS 0,9

Bit				
1	MSB		**1**	
2			**0**	
3	FORMAT TYPE CODE = 19		**0**	
4			**1**	
5	LSB		**1**	
6	SUBTYPE 1 0		SUBTYPE 2 0	
7	0		1	
8	1		0	
9	**INTENT CHANGE FLAG (A.1.4.5.3)**			
10	IFR CAPABILITY FLAG			
11	NAVIGATION UNCERTAINTY			
12	CATEGORY – VELOCITY			
13	(NUC_R)			
14	DIRECTION BIT for E-W velocity **(0=East, 1=West)**			
15	EAST-WEST VELOCITY (10 bits)			
16	NORMAL : LSB = 1 knot		SUPERSONIC : LSB =4 knots	
17	All zeros = no velocity info		All zeros = no velocity info	
18	Value	Velocity	Value	Velocity
19	1	0 kts	1	0 kt
20	2	1 kt	2	4 kt
21	3	2 kt	3	8 kt
22	-	-	-	-
23	1022	1021 kt	1022	4084 kt
24	1023	>1021.5 kt	1023	> 4086kt
25	DIRECTION BIT for N-S velocity **(0=North, 1=South)**			
26	NORTH-SOUTH VELOCITY (10 bits)			
27	NORMAL : LSB = 1 knot		SUPERSONIC : LSB =4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kt
31	2	1 kt	2	4 kt
32	3	2 kt	3	8 kt
33	-	-	-	-
34	1022	1021 kt	1022	4084 kt
35	1023	>1021.5 kt	1023	> 4086kt
36	SOURCE BIT FOR VERTICAL RATE: 0 = Geometric, 1 = baro (1 bit)			
37	SIGN BIT FOR VERTICAL RATE: 0 = up, 1 = down			
38	VERTICAL RATE (9 bits)			
39	All zeros – no vertical rate information, LSB = 64 ft/min			
40	Value	Vertical rate	Ref. ARINC 429 labels	
41	1	0 ft/min	GPS: 165	
42	2	64 ft/min	INS: 365	
43	-	-		
44	510	32576 ft/min		
45	511	> 32608 ft/min		
46				
47	TURN INDICATOR (2 bits)			
48	TBD			
49	DIFFERENCE SIGN BIT (0 = above baro, 1 = below baro alt)			
50	GEOMETRIC HEIGHT DIFFERENCE FROM BARO. ALT. (7 bits) (A.1.4.5.6)			
51	All zeros = no info; LSB = 25 ft			
52	Value	Difference		
53	1	0 ft		
54	2	25 ft		
55	-	-		
56	126	3125 ft		
	127	> 3137.5 ft		

Purpose: To provide additional state information for both normal and supersonic flight.

Subtype Coding

Code	Velocity	Type
0	As in first edition of the ICAO Manual on Mode S Specific Services	
1	Ground speed	normal
2		supersonic
3	Airspeed, heading	normal
4		supersonic
5	Not assigned	
6	Not assigned	
7	Not assigned	

IFR Capability Flag coding:

0 = Transmitting aircraft has no capability for applications requiring ADS-B equipage class A1 or above

1 = Transmitting aircraft has capability for applications requiring ADS-B equipage class A1 or above.

Ref. ARINC Labels for Velocity:

East-West	North-South
GPS: 174	GPS: 166
INS: 367	INS: 366

Ref. ARINC Labels
GNSS Height (HAE): GPS: 370
GNSS Altitude (MSL): GPS: 076

Navigation Uncertainty Category:
See the definition of NUC_R in subparagraph 2.2.3.2.6.1.5.

Figure A-7: Extended Squitter Airborne Velocity (Subtypes 3 and 4: Airspeed and Heading)

BDS 0,9

Bit				
1	MSB			**1**
2				**0**
3	FORMAT TYPE CODE = 19			**0**
4				**1**
5	LSB			**1**
6	SUBTYPE 3	0	SUBTYPE 4	1
7		1		0
8		1		0
9	**INTENT CHANGE FLAG (A,4.5.3)**			
10	IFR CAPABILITY FLAG			
11	NAVIGATION UNCERTAINTY			
12	CATEGORY – VELOCITY			
13	(NUC_R)			
14	STATUS BIT – 1 = Magnetic heading available, 0 = not available			
15	MSB			
16				
17				
18	MAGNETIC HEADING (10 bits)			
19	(A.1.4.5.5)			
20				
21				Ref. ARINC 429 Label:
22				INS: 320
23	Resolution = 360/1024 deg			
24	LSB			
25	AIRSPEED TYPE: 0 = IAS, 1 = TAS			
26	AIRSPEED (10 bits)			
27	NORMAL : LSB = 1 knot		SUPERSONIC : LSB =4 knots	
28	All zeros = no velocity info		All zeros = no velocity info	
29	Value	Velocity	Value	Velocity
30	1	0 kts	1	0 kt
31	2	1 kt	2	4 kt
32	3	2 kt	3	8 kt
33	-	-	-	-
34	1022	1021 kt	1022	4084 kt
35	1023	>1021.5 kt	1023	> 4086 kt
36	SOURCE BIT FOR VERTICAL RATE: 0 = Geometric, 1 = baro (1 bit)			
37	SIGN BIT FOR VERTICAL RATE: 0 = up, 1 = down			
38	VERTICAL RATE (9 bits)			
39	All zeros – no vertical rate information			
40	LSB = 64 ft/min			
41	Value	Vertical rate	Ref. ARINC labels	
42	1	0 ft/min	GPS: 165	
43	2	64 ft/min	INS: 365	
44	-	-		
45	510	32576 ft/min		
46	511	> 32608 ft/min		
47	TURN INDICATOR (2 bits)			
48	TBD			
49	DIFFERENCE SIGN BIT (0 = above baro, 1 = below baro alt))			
50	GEOMETRIC HEIGHT DIFFERENCE FROM BARO. ALT. (7 bits) (A.1.4.5.6)			
51	All zeros = no info; LSB = 25 ft			
52	Value	Vertical rate	Ref. ARINC 429 labels	
53	1	0 ft		
54	2	25 ft		
55	-	-		
56	126	3125 ft		
	127	> 3137.5 ft		

Purpose: To provide additional state information for both normal and supersonic flight based on airspeed and heading.

Note: *This format is only used if velocity over ground is not available*

See the definition of NUC_R in section 2.2.3.2.6.1.5.

Subtype Coding

Code	Velocity	Type
0	As in first edition of the ICAO Manual on Mode S Specific Services	
1	Ground speed	normal
2		supersonic
3	Airspeed, heading	normal
4		supersonic
5	Not assigned	
6	Not assigned	
7	Not assigned	

IFR Capability Flag coding:

0 = Transmitting aircraft has no capability for applications requiring ADS-B equipage class A1 or above

1 = Transmitting aircraft has capability for applications requiring ADS-B equipage class A1 or above.

Ref. ARINC 429 Labels for Air Data Source:
IAS: 206
TAS: 210

Figure A-8: Extended Squitter Event Driven Register

BDS 0,A	
1	
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Purpose. To provide a flexible means to squitter messages other than position, velocity and identification.

Notes:

1. *A message inserted in this register (or an equivalent transmit register) is broadcast once by the transponder at the earliest opportunity.*

2. *Formats for messages using this protocol are defined in registers 6,1 to 6,F.*

3. *The GFM (A.1.6) is responsible for ensuring pseudo-random timing and for observing the maximum transmission rate for this register of 2 per second.*

4. *The data in this register is not intended for extraction using the GICB or TCAS crosslink protocols. Readout (if required) is accomplished by extracting the contents of the appropriate register 6,1 to 6,F.*

Figure A-9: Extended Squitter Aircraft Status
(Subtype 1: Emergency/Priority Status)

BDS 6,1

Bits	Field
1–5	FORMAT TYPE CODE = 28
6–8	Subtype Code = 1
9–11	EMERGENCY/PRIORITY STATUS (3 bits)
12–56	RESERVED

Purpose. To provide additional information on aircraft status.

Subtype Coding:

0	=	No Information
1	=	Emergency/Priority Status
2-7	=	Reserved

Emergency/Priority Status Coding

Value	*Meaning*
0	No emergency
1	General emergency
2	Lifeguard/medical
3	Minimum fuel
4	No communications
5	Unlawful interference
6	Reserved
7	Reserved

Notes:

1. *Message delivery is accomplished once per second using the event driven protocol.*

2. *Termination of emergency state is detected by coding in the surveillance status field of the airborne position message.*

Figure A-10: Current/Next Trajectory Change Point (TCP, TCP+1)

BDS 6,2: TCP

BDS 6,3: TCP+1

Purpose. To provide aircraft intent as defined by the current or next trajectory change point.

1		
2		
3	FORMAT TYPE CODE = 29	
4		
5		
6	TCP Type (0=current, 1=next)	
7	TRAJECTORY POINT/LEG	
8	TYPE	
9	(See A.1.4.9.3)	
10		
11	TCP DATA VALID (0=invalid,1=valid)	
12	TCP Format (0=4D TCP)	TCP Format (1=3D TCP)
13	MSB	MSB
14	TCP, TCP+1	TCP, TCP+1
15	ALTITUDE	ALTITUDE
16		
17	(See A.1.4.9.6)	(See A.1.4.9.6)
18		
19		
20		
21		
22	LSB	LSB
23	MSB	MSB
24	TCP, TCP+1	TCP, TCP+1
25	LATITUDE	LATITUDE
26	(CPR Even Format Coding)	(Angular weighted binary coding)
27	(See A.1.4.9.71)	(See A.1.4.9.7.2)
28		
29		
30		
31		
32		
33		
34		
35		
36	LSB	
37	MSB	
38	TCP, TCP+1	
39	LONGITUDE	LSB = 2^{-17} x 360 degrees
40	(CPR Even Format Coding)	MSB
41		TCP, TCP+1
42	(See A.1.4.9.8.1)	LONGITUDE
43		(Angular weighted binary coding)
44		(See A.1.4.9.8.2)
45		
46		
47		
48		
49		
50	LSB	
51	MSB	
52	TCP, TCP+1	
53	TIME-TO-GO (TTG)	
54		
55	(See A.1.4.9.9)	
56	LSB	LSB = 2^{-17} x 360 degrees

Figure A-11: Aircraft Operational Coordination Message

BDS 6,4

Bits	Field
1–5	FORMAT TYPE CODE = 30
6–8	Subtype Code=0
9–32	MSB (bit 9) Paired Address (See A.1.4.10.3) LSB (bit 32)
33–37	MSB (bit 33) Runway Threshold Speed (See A.1.4.10.4) LSB (bit 37)
38	Roll Angle sign (See A.1.4.10.5)
39–43	MSB (bit 39) Roll Angle (See A.1.4.10.6) LSB (bit 43)
44–45	Go Around (See A.1.4.10.7)
46–47	Engine Out (See A.1.4.10.8)
48–56	Not Assigned

Purpose. To provide the current state of the various aircraft parameters required to support operational applications, particularly those involving paired aircraft.

Figure A-12: Aircraft Operational Status

BDS 6,5

Bit	Field
1	MSB
2	
3	FORMAT TYPE CODE = 31
4	
5	LSB
6	MSB
7	Subtype Code=0
8	LSB
9	MSB
10	Enroute Operational Capabilities (CC-4)
11	(See A.1.4.11.3)
12	LSB
13	MSB
14	Terminal Area Operational Capabilities(CC-3)
15	(See A.1.4.11.4)
16	LSB
17	MSB
18	Approach/ Landing Operational Capabilities (CC-2)
19	(See A.1.4.11.5)
20	LSB
21	MSB
22	Surface Operational Capabilities (CC-1)
23	(See A.1.4.11.6)
24	LSB
25	MSB
26	Enroute Operational Capability Status (OM –4)
27	(See A.1.4.11.7)
28	LSB
29	MSB
30	Terminal Area Operational Capability Status (OM-3)
31	(See A.1.4.11.8)
32	LSB
33	MSB
34	Approach/ Landing Operational Capability Status (OM-2)
35	(See A.1.4.11.9)
36	LSB
37	MSB
38	Surface Operational Capability Status (OM-1)
39	(See A.1.4.11.10)
40	LSB
41	MSB
42	Version Number (VN) (See A.1.4.11.11)
43	LSB
44	
45	
46	
47	Not Assigned
48	
49	
50	
51	
52	
53	
54	
55	
56	

Purpose. To provide the capability class and current operational mode of ATC related applications on board the aircraft.