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RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision B

Meeting #28

Requirements and Test Procedures for Processing Position Time of Applicability in ADS-B Receivers In Response to Action Item 26-07

Revision 1

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SUMMARY

Recommended requirements and test procedures for processing Position Time of Applicability in ADS-B Receivers are presented. Three cases are defined: T=0, T=1 when receiver has a UTC time reference and T=1 when receiver does NOT have a UTC time reference.

1 Background

Requirements and test procedures for Time of Applicability (TOA) reporting in DO-260A do not address TOA processing when T=1.

2.2.8.1.4.2 Position Time of Applicability

Each time that an Airborne or Surface Position Message is received with valid Latitude AND Longitude data, the Report Assembly Function shall update the Position Time of Applicability data in the State Vector Report with either the GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) or the Established Receiver Unit Time (see §2.2.8.4.2), whichever is applicable to the Receiving device Report Assembly Function installation requirements.

TOA reporting requirements are defined in §2.2.8.1.4.2 but requirements for choosing the appropriate 200ms UTC epoch are not specified.

§A.1.4.2.3.1 specifies the correct procedure for determining the 200ms UTC epoch for TOA, but material in Appendix A is not mandatory in the context of DO-260A and DO-260A contains no test procedures to verify any behavior specified solely in an appendix.

A.1.4.2.3.1 Extrapolating Position (When T=1)

[Text deleted]

This timing ensures that the ADS-B Receiving Subsystem 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.

There are requirements for extrapolating position to a specific 200 ms UTC epoch and encoding the result, and the Format (F) bit, in the following sections of DO-260A:

a. §2.2.3.2.3.5 “TIME” (T) Subfield in ADS-B Airborne Position Messages

b. §2.2.3.2.3.6 “CPR Format” (F) Subfield in ADS-B Airborne Position Messages

c. 2.2.3.2.3.7.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, “TIME” (T) = “1”) [Airborne Latitude]

d. 2.2.3.2.3.8.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, “TIME” (T) = “1”) [Airborne Longitude]

e. 2.2.3.2.4.5 “TIME” (T) Subfield in ADS-B Surface Position Messages

f. 2.2.3.2.4.6 “CPR Format” (F) Subfield in ADS-B Surface Position Messages

g. 2.2.3.2.4.7.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, “TIME” (T) = “1”) [Surface Latitude]

h. 2.2.3.2.4.8.2.1 GPS/GNSS Time Mark Coupled Case (Extrapolation, “TIME” (T) = “1”) [Surface Longitude]

None of the sections listed above specify how to determine TOA when a position message is received with T=1.

None of the test procedures for the sections listed above cover the case of determining TOA from a position message received with T=1.

The remainder of the paper proposes additional requirements for Section §2.2.8.1.4.2 and additional test procedures in §2.4.8.1.4.2 to address TOA processing for reports when receiving position messages with T=1.

2 Recommended Requirements Changes and Impact Analysis

2.1 Proposed Requirements Changes

There are three cases to consider when processing Position Time of Applicability.

- Case 1: T=0
- Case 2: T=1 and UTC Time of Message Receipt (TOMR) is Available
- Case 3: T=1 and UTC TOMR is NOT available

Section §2.2.8.1.4.2 should be rewritten to address the three cases as follows.

(2.2.8.1.4.2) Position Time of Applicability

Processing of Position Time of Applicability depends on the UTC Time of Message Receipt of the position message and the value of the “TIME” (T) bit in the position message. ~~Time of Message Receipt is when the power level of the leading edge of the P1 pulse of the received extended squitter message is 3 dB below the power level of the top of the P1 pulse.~~

(2.2.8.1.4.2.1) Position Time of Applicability when “TIME” (T) = “0”

Each time that an Airborne or Surface Position Message is received with valid Latitude AND Longitude data and “TIME” (T) = “0”, the Report Assembly Function **shall** update the Position Time of Applicability data in the State Vector Report with the Time of Message Receipt of the position message expressed as either the GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) or the Established Receiver Unit Time (see §2.2.8.4.2). Time of Applicability **shall** be rounded to the nearest LSB of the Position Time of Applicability field.

(2.2.8.1.4.2.2) Position Time of Applicability when “TIME” (T) = “1” and UTC Time of Message Receipt is available

Each time that an Airborne or Surface Position Message is received with “TIME” (T) = “1” and valid Latitude AND Longitude data, and when a valid UTC Time of Message Receipt is available per §2.2.8.4.1, the Report Assembly Function **shall** update the Position Time of Applicability data in the State Vector Report with the appropriate 0.2 second UTC epoch. The appropriate 0.2 second UTC epoch is determined as follows:

- If "CPR Format" (F) = 0, Position Time of Applicability **shall** be the nearest even 0.2 second UTC epoch to the time that the Airborne Position Message is received, expressed as GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) and rounded to the nearest LSB of the Position Time of Applicability field.

- If "CPR Format" (F) = 1, Position Time of Applicability **shall** be the nearest odd 0.2 second UTC epoch to the time that the Airborne Position Message is received, expressed as GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) and rounded to the nearest LSB of the Position Time of Applicability field.

Note: An "even 0.2 second UTC epoch" is defined as that moment on the UTC time that occurs at an even number of 200-millisecond intervals after an exact even-numbered UTC second. Likewise, an "odd 0.2 second UTC epoch" is defined as that moment on the UTC time scale that occurs at an odd number of 200 millisecond intervals after an even numbered UTC second. Examples of even 0.2 second epochs are 12.0 seconds, 12.4 seconds, 12.8 seconds, 13.2 seconds, 13.6 seconds, etc. Examples of odd 0.2 second epochs are 12.2 seconds, 12.6 seconds, 13.0 seconds, 13.4 seconds, 13.8 seconds, etc.

(2.2.8.1.4.2.3) Position Time of Applicability when "TIME" (T) = "1" and UTC Time of Message Receipt is NOT available

Each time that an Airborne or Surface Position Message is received with "TIME" (T) = "1" and valid Latitude AND Longitude data, and when no valid UTC Time of Message Receipt per §2.2.8.4.1 is available, the Position Time of Applicability **shall** be processed as specified in §2.2.8.1.4.2.1.

2.2 Analysis of Changes

2.2.1 Case 1 (T=0)

The requirement is essentially the same as DO-260A. The following changes are recommended to improve clarity:

- Stipulate that the requirement applies when "TIME" (T) = 0
- State that reported Position TOA = TOMR of the position message. The existing requirement to update the Position TOA with "UTC Measure Time data" per §2.2.8.4.1 or "Established Receiver Unit Time" per §2.2.8.4.2 is not clear enough. Sections §2.2.8.4.1 and §2.2.8.4.2 describe how to express time but they do not specifically address TOMR or TOA.
- Add a requirement to round TOA to the nearest LSB so there is no ambiguity between rounding and truncating.

2.2.2 Case 2 (T=1 and UTC TOMR is available)

This requirement is new. This case is not addressed by existing requirements. The requirements for picking the nearest even or odd epoch are taken A.1.4.2.3.1. Text has been added to specify that time is expressed as "UTC Measure Time Data" per §2.2.8.4.1 and that the resulting TOA must be rounded to the nearest LSB of the Position TOA field. A note, copied from §2.2.3.2.3.6, was added to remind the reader of the meaning of even and odd epochs.

2.2.3 Case 3 (T=1 and UTC TOMR is NOT available)

If the transmitting aircraft sends a position message with T=1 and the receiving system does not have the capability to determine the TOMR with respect to UTC, the receiving system will not be able to associate the TOA with an even or odd 0.2 second UTC epoch. The receiving system has two options:

- Drop all messages with T=1
- Process messages with T=1 and report the position TOA as the TOMR of the position message.

The first option would have a negative impact on operational application performance and was dropped from consideration. The second option is viable but has some consequences that might or might not impact operational applications.

Figure 1 presents a timeline of position message encoding, transmission and reception when T=1. In the nominal case, the position register is loaded with latitude and longitude extrapolated to the next 0.2 second even or odd UTC epoch 100ms before the epoch. The arrows labeled “Load Register” at 0.1 and 0.3 seconds depict this nominal scenario with the position extrapolated to 0.2 seconds (an odd epoch). The Transmit function can transmit the contents of the register at any time. If the position message is sent at any time between 0.1 and 0.3 seconds, the position data contained in the message will have been extrapolated to 0.2 seconds. A UTC synchronized receiver will choose 0.2 as the TOA because the TOMR will be between 0.1 and 0.3, the F bit will be 1 (odd) and the nearest odd epoch will be 0.2 seconds.

An extreme case is shown in Figure 1 between 0.45 and 0.75 seconds. Even in this scenario, a UTC synchronized receiver will associate the TOA with the correct UTC epoch.

If the receiver is not UTC synchronized, the only TOA processing option for the receiver is to assume that TOA is equal to TOMR. In the nominal case, the difference between the TOMR and the TOA of the data in the position message (i.e. the time to which the latitude and longitude were extrapolated) would always be less than 100ms. In the extreme case, the difference could be as much as 150ms. The proposed requirement text assumes that this time difference is negligible for operational applications. If the difference is significant, compensation of NACp and NIC may be required.

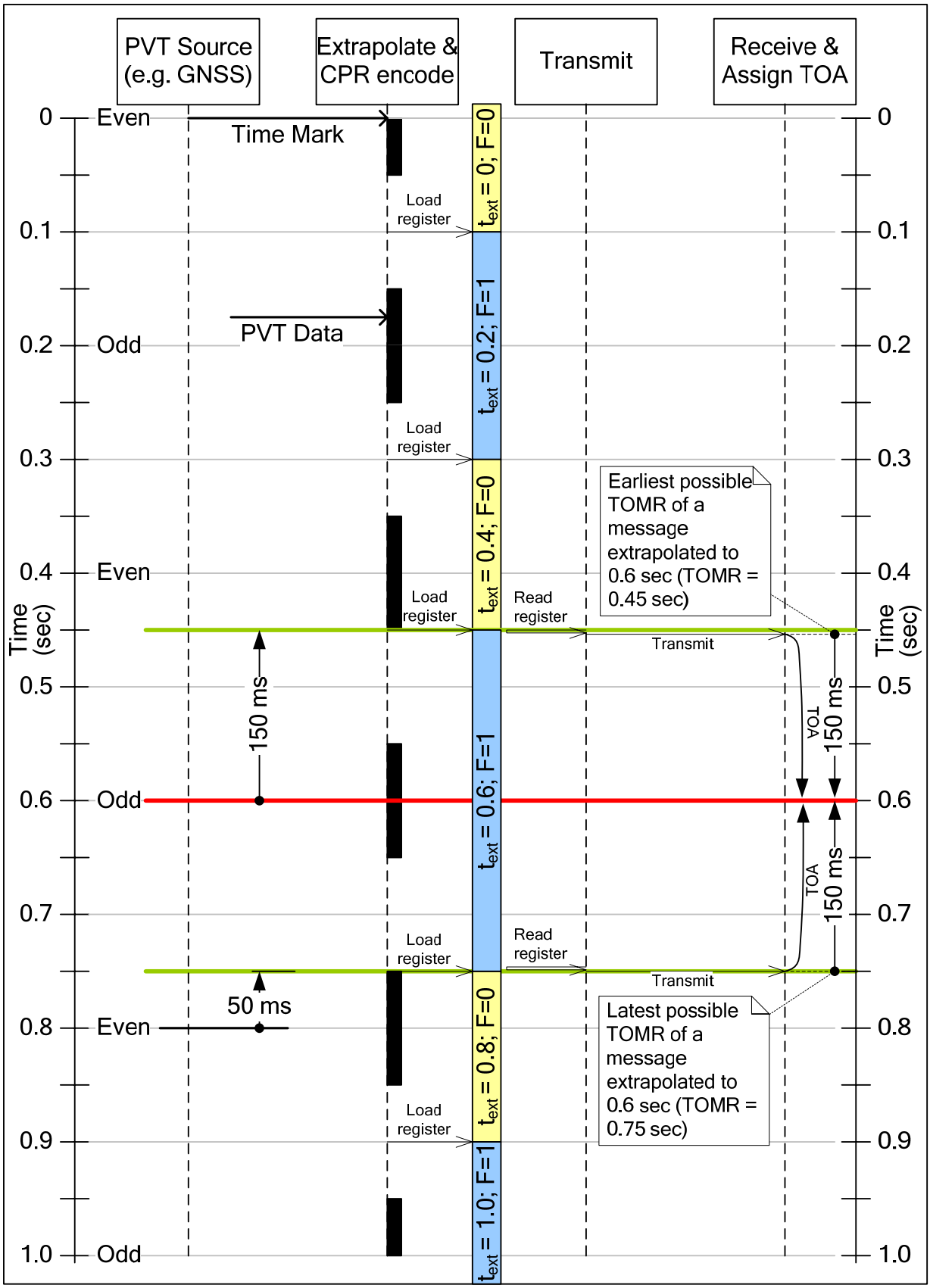

Figure 1 - TOA Processing When T=1

3 Recommended Test Procedures

3.1 Issues with Existing Test Procedures

The existing test procedures for Airborne Position Time of Applicability in Step 1 of §2.4.8.1.4.2 have several issues:

1. The test procedures only address the first and third cases in the proposed requirements.

2. The test procedure does not verify the essential requirement that TOA = TOMR.

3. Step 1 of the procedure requires the generation of a series of even and odd airborne position messages over a 10 second period but does not specify the interval between the messages. If the user schedules the messages with intervals greater than or equal to 500ms, the differences between TOAs of successive messages will exceed the "less than 500ms" criterion in the third paragraph of Step 1.

4. The bit references in the second paragraph do not match the descriptions given in Tables 2-83 and 2-84. The last sentence of the second paragraph is redundant with the first clause of the first sentence.

5. The byte reference in the third paragraph does not match the description in Table 2-81.

6. The fifth paragraph seems to verify that when the latitude and longitude are invalid and the Position Time of Applicability field is present, the value of the Position TOA field is all zeroes. The requirement for this behavior is not given in §2.2.8.1.4.2 (Position TOA), §2.2.8.1.5 (Latitude) or §2.2.8.1.6 (Longitude).

The test procedures for Surface Position Time of Applicability in Step 2 of §2.4.8.1.4.2 have similar problems.

3.2 Proposed Test Procedures

(2.4.8.1.4.2) Verification of Position Time of Applicability (§2.2.8.1.4.2)

Appropriate test procedures required to validate the requirements of §2.2.8.1.4.2 are included in the following subparagraphs.

(2.4.8.1.4.2.1) Verification of Position Time of Applicability when "TIME" (T) = "0" (§2.2.8.1.4.2.1)

<u>Purpose/Introduction:</u>

Each time that an Airborne or Surface Position Message is received with valid Latitude AND Longitude data and "TIME" (T) = "0", the Report Assembly Function **shall** update the Position Time of Applicability data in the State Vector Report with the Time of Message Receipt of the position message expressed as either the GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) or the Established Receiver Unit Time (see §2.2.8.4.2). Time of Applicability **shall** be rounded to the nearest LSB of the Position Time of Applicability field.

Measurement Procedure:

Step 1: Position Time of Applicability for Airborne Position Messages When "TIME" (T) = 0

The unit under test must be capable of receiving messages and producing state vector reports. A stimulus capable of forming and transmitting compliant 1090ES messages at specific times and an apparatus for analyzing State Vector Report contents are required.

Generate a series of Airborne Position Messages per Table 3-1 which have a stable TYPE code and include encoded data ("ME" Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position. The latitude and longitude in each message shall be unique among the latitudes and longitudes used in the set of messages.

Ensure that the unit under test does not have a track file for the target address used in the Position Messages. Inject the Position messages into the unit under test at the times shown in the "Receiver Input Time" column of Table 3-1. Verify that the difference in Position TOA between State Vector Reports matches the value in the "TOA Difference Between Reports" column of Table 3-1 rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report match the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each position message.

Note: The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.5 using the latitudes and longitudes that were CPR encoded into the position messages.

Table 3-1 - Position Message Contents for Position TOA Verification When T=0

CPR Format (F)	Receiver Input Time (UTC sec)	TOA Difference Between Reports	Comment
0	t_0	No Report	
1	$t_0 + 0.5$	First Report	First global decode complete
0	$t_0 + 0.9$	0.40	
1	$t_0 + 1.5$	0.60	Second global decode complete
1	$t_0 + 2.05$	0.55	
0	$t_0 + 2.55$	0.50	

Step 2: Position Time of Applicability for Surface Position Messages When "TIME" (T) = 0

Repeat Step 1 using surface position messages. Verify that the difference in Position TOA between State Vector Reports matches the value in the "TOA Difference Between Reports" column of Table 3-2 rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report match the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each position message.

Note: The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.6 using the latitudes and longitudes that were CPR encoded into the position messages.

(2.4.8.1.4.2.2) Verification of Position Time of Applicability when "TIME" (T) = "1" and UTC Time of Message Receipt is available (§2.2.8.1.4.2.2)

Purpose/Introduction:

Each time that an Airborne or Surface Position Message is received with "TIME" (T) = "1" and valid Latitude AND Longitude data, and when a valid UTC Time of Message Receipt is available per §2.2.8.4.1, the Report Assembly Function **shall** update the Position Time of Applicability data in the State Vector Report with the appropriate 0.2 second UTC epoch. The appropriate 0.2 second UTC epoch is determined as follows:

- If "CPR Format" (F) = 0, Position Time of Applicability **shall** be the nearest even 0.2 second UTC epoch to the time that the Airborne Position Message is received, expressed as GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) and rounded to the nearest LSB of the Position Time of Applicability field.

- If "CPR Format" (F) = 1, Position Time of Applicability **shall** be the nearest odd 0.2 second UTC epoch to the time that the Airborne Position Message is received, expressed as GPS/GNSS UTC Measure Time data (see §2.2.8.4.1) and rounded to the nearest LSB of the Position Time of Applicability field.

Measurement Procedure:

Step 1: Position Time of Applicability for Airborne Position Messages When "TIME" (T) = 1 and UTC Time of Message Receipt is available

The unit under test must be provided with a UTC time reference, and must be capable of receiving messages and producing state vector reports. A stimulus capable of forming and transmitting compliant 1090ES messages at specific UTC times and a UTC time reference for this stimulus are required. An apparatus for capturing State Vector Reports and analyzing their contents is also required.

Generate a series of Airborne Position Messages per Table 3-2 which have a stable TYPE code and include encoded data ("ME" Bits 23 - 39 for Latitude, and Bits 40 - 56 for Longitude) for both valid Latitude and valid Longitude based on any convenient starting position. The latitude and longitude in each message shall be unique among the latitudes and longitudes used in the set of messages.

Ensure that the unit under test does not have a track file for the target address used in the Position Messages. Inject the Position messages into the unit under test at the times shown in the "Receiver Input Time" column of Table 3-2. Verify that the Position TOA in the State Vector Reports matches the value in the "Expected Position TOA" column of Table 3-2 rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report match the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each position message.

Note: The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.5 using the latitudes and longitudes that were CPR encoded into the position messages.

Table 3-2 Messages for Position TOA Verification when T=1

TOA of Lat/Lon in Position Message	CPR Format (F)	Receiver Input Time (UTC sec)	Expected Position TOA	Comment
t_{even} + 0	0	t_{even} + 0	No Report	
t_{even} + 0.6	1	t_{even} + 0.5	t_{even} + 0.6	First global decode complete
t_{even} + 0.8	0	t_{even} + 0.9	t_{even} + 0.8	
t_{even} + 1.4	1	t_{even} + 1.5	t_{even} + 1.4	Second global decode complete
t_{even} + 2.2	1	t_{even} + 2.05	t_{even} + 2.2	New data loaded and transmitted at the beginning of the 50-150ms window
t_{even} + 2.4	0	t_{even} + 2.55	t_{even} + 2.4	Old data transmitted at the end of the 50-150 ms window just before loading of new data

Note: t_{even} is any even integer UTC second

Step 2: Position Time of Applicability for Surface Position Messages When "TIME" (T) = 1 and UTC Time of Message Receipt is available

Repeat Step 1 using surface position messages. Verify that the Position TOA in the State Vector Reports matches the value in the "Expected Position TOA" column of Table 3-2 rounded to the nearest LSB. Verify that the Latitude and Longitude in each State Vector Report match the CPR Coordinate Latitude and Longitude of the CPR Coordinates used in each position message.

Note: The CPR Coordinate Latitude is determined with the Locally Unambiguous CPR Decoding procedure in §A.1.7.6 using the latitudes and longitudes that were CPR encoded into the position messages.

(2.4.8.1.4.2.3) Verification of Position Time of Applicability when "TIME" (T) = "1" and UTC Time of Message Receipt is NOT available (§2.2.8.1.4.2.3)

Purpose/Introduction:

Each time that an Airborne or Surface Position Message is received with "TIME" (T) = "1" and valid Latitude AND Longitude data, and when no valid UTC Time of Message Receipt per §2.2.8.4.1 is available, the Position Time of Applicability **shall** be processed as specified in §2.2.8.1.4.2.1.

Measurement Procedure:

The requirement in §2.2.8.1.4.2.3 is verified using the procedure specified in §2.4.8.1.4.2.1.