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ADS-B 1090ES MOPS Maintenance
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Proposed section §2.2.3.2.3.7
"Encoded Latitude" Subfield in ADS-B Airborne Position Messages
In Response to Action Item 28-02

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Summary
Full proposal for section 2.2.3.2.3.7. If the Working Group agrees to changes, then text will be incorporated in sections 2.2.3.2.3.7, 2.2.3.2.3.8, 2.2.3.2.4.7, and 2.2.3.2.4.8 (Airborne Latitude, Airborne Longitude, Surface Latitude, and Surface Longitude, respectively)

2.2.3.2.3.7 "Encoded Latitude" Subfield in ADS-B Airborne Position Messages

The "Encoded Latitude" subfield is a 17-bit ("ME" bit 23 through 39, Message bit 55 through 71) field containing the encoded latitude of the airborne position.

2.2.3.2.3.7.1 Airborne Latitude Data Encoding

The airborne latitude position data **shall** be encoded in accordance with §A.1.4.2.2 and §A.1.7 of Appendix A.

2.2.3.2.3.7.2 GPS/GNSS Time Mark Coupled Case ("TIME" (T) = "1")

If "TIME" (T) = 1 (see §**Error! Reference source not found.**) in an Airborne Position Message, then the transmit time of applicability (see Appendix TBD) of the latitude field in that message **shall** be an exact 0.2 second UTC epoch.

a. Specifically, the position data in the latitude and longitude fields **shall** be extrapolated forward from the time of validity of the position fix to the transmit time of applicability of the Airborne Position Message.

b. The Airborne latitude data registers and the encoded latitude subfield **shall** be updated every 200 milliseconds to the next 0.2 UTC Epoch using the velocity data provided for the position fix.

Notes:

1. *The time of validity of the fix is provided with the fix data from the navigation data source and is indicated by the leading edge of the GNSS Time Mark (see §**Error! Reference source not found.**). The transmit time of applicability of the position message is the exact 0.2 second UTC Epoch to which the transmitted position data is extrapolated.*

2. *The latitude position registers and encoded latitude subfield should be updated at a time about 100 milliseconds before the time of applicability of the data being loaded into that register (see §**Error! Reference source not found.** and Appendix A, §A.1.4.2.3.1).*

3. *One method of estimating the position to an exact 0.2 second UTC Epoch is described in the following "Commentary."*

COMMENTARY:

*The following example provides one method (not the only method) that latitude given in the Airborne Position Message may be extrapolated from the time of validity of the fix (included with the fix from the navigation data source) to the time of applicability of the Airborne Position Message. In the example, it is assumed that the "TIME" (T) subfield (see §**Error! Reference source not found.**) is "ONE," indicating that the time of applicability of the extrapolated position is an exact 0.2 second UTC Epoch. See Appendix TBD for a discussion of timing.*

Let:

t_{fix}	=	*the time of the leading edge of the last received GNSS Time Mark (see §**Error! Reference source not found.**), which is also the time of validity included with the fix from the navigation data source.*
$t_{message}$	=	*the transmit time of applicability of the Airborne Position Message, which is an exact 0.2 second UTC Epoch.*
Δt	=	$t_{message} - t_{fix}$, *in milliseconds*
ϕ_{fix}	=	*last known latitude position, at time* t_{fix}, *in degrees*
$\phi_{message}$	=	*latitude, extrapolated forward to the time of applicability of the Airborne Position Message,* $t_{message}$
$\Delta\phi$	=	$\phi_{message} - \phi_{fix}$, *in degrees*
v_{NS}	=	*North/South Velocity*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\phi_{message} = \phi_{fix} + \Delta\phi$$

$$= \phi_{fix} + (v_{NS}/60)(\Delta t/3600000)$$

$$= \phi_{fix} + (v_{NS}\,\Delta t) / (2.16 \times 10^{8})$$

(We divide v_{NS} *by 60 to convert from knots in the N-S direction to degrees of latitude per hour, and divide* Δt *by 3600 x 1000 to convert from milliseconds to hours.)*

The result, $\phi_{message}$, *is to be encoded in the latitude field of the Airborne Position Message using the CPR algorithm described in Appendix A, §A.1.7.*

2.2.3.2.3.7.3 Non-GPS/GNSS Time Mark Coupled Case ("TIME" (T) = "0")

The ADS-B Transmitting subsystem provides position in the non-GNSS time mark coupled case ("TIME" (T) = "0") that is understood by receiving systems to be applicable at the time of reception rather than UTC time synchronized points in time. Therefore, in the non-GNSS time mark coupled case, the ADS-B transmitting subsystem attempts to provide the position data to within a specified time tolerance of the time of transmission. For such transmitted position data, the ADS-B Transmitting subsystem is not required to accept and process the GPS/GNSS Time Mark information. The time of applicability of the Latitude information provided to the variable data input interface (§2.2.5.1.7) is unknown to the ADS-B Transmitting subsystem. Position data is extrapolated/estimated within the accuracy criteria specified below based on the assumption that the time of applicability of the position data is the time that the data is received at the input interface.

Prior to or at the time of transmission of the position data, position data is updated to account for the delay between the time it arrived at the input of the

ADS-B transmitting subsystem and the time it is transmitted. This can be accomplished by several acceptable means. One acceptable method is to periodically perform a straight linear extrapolation of the position data using the velocity provided and the time difference between the previous update and the time of applicability used for the extrapolation. Whatever means are implemented, the following represents the minimum performance requirement:

The time of applicability to which the position data is computed **shall** be such that the position data in the transmitted message is within 100 milliseconds of the time of applicability of the position at the time of transmission.

For these purposes, the time of applicability of the position data at the time of transmission is computed from a linear extrapolation of the position with the assumption that the time of applicability of the position provided through the appropriate variable data interface is equal to the time it arrives at the input to the ADS-B transmitting subsystem.

Note: It is not acceptable to compute the extrapolated position based on any assumption that the time of applicability of the position provided at the input to the ADS-B transmitting subsystem is later than the time it arrives at the input. Any delays between the data arriving at the input and being recognized by the ADS-B transmitting subsystem must either be accounted for by extrapolation or understood to comprise a portion of the 100 millisecond budget allowed by the requirements.

Note: It is acceptable to compute the extrapolated position based on an assumption that the time of applicability of the position provided at the input to the ADS-B transmitting subsystem is earlier than the time it arrives at the input, provided that a verifiable estimation of the delay between the true time of applicability of the position fix and the provision of that fix to the ADS-B transmitting subsystem's data interface is possible. Such methods are beyond the minimum requirements and will need to be certified using appropriately modified test procedures.

COMMENTARY:

*The following example provides one method (not the only method) that latitude given in the Airborne Position Message may be extrapolated from the time that the data arrives at the input to the ADS-B transmitting subsystem to the time of applicability of the position data at the time of transmission. In the example, it is assumed that the "TIME" (T) subfield (see §**Error! Reference source not found.**) is "ZERO," indicating that the transmit time of applicability of the extrapolated position is the time of transmission. No attempt is made to compensate for delays prior to the delivery of latitude data to the appropriate variable interface.*

Let:

$t_{interface}$ = *time when the the most recent PVT (position, velocity, time) data from a navigation data source crosses the data interface to the ADS-B Transmitting subsystem.*

t_{fix}	=	*true time of applicability of the last known latitude position, received by the ADS-B Subsystem at time* $t_{interface}$.
$t_{message}$	=	*the transmit time of applicability of the Airborne Position Message, which is the time of transmission.*
Δt	=	*total amount of extrapolation forward performed by the ADS-B Subsystem, in milliseconds*
ϕ_{fix}	=	*last known latitude position, received by the ADS-B Subsystem at time* $t_{interface}$*, in degrees*
$\phi_{message}$	=	*latitude, extrapolated forward to the time of applicability of position data at the time of transmission.*
$\Delta\phi$	=	$\phi_{message} - \phi_{fix}$*, in degrees*
v_{NS}	=	*North/South Velocity*

The earth may be modeled as a sphere with radius such that one nautical mile equals one minute of arc along a great circle. Using that approximation, yields:

$$\begin{aligned} \phi_{message} &= \phi_{fix} + \Delta\phi \\ &= \phi_{fix} + (v_{NS}/60)(\Delta t\ /3600000) \\ &= \phi_{fix} + (v_{NS}\ \Delta t) / (2.16 \times 10^{8}) \end{aligned}$$

(We divide v_{NS} *by 60 to convert from knots in the N-S direction to degrees of latitude per hour, and divide* Δt *by 3600 x 1000 to convert from milliseconds to hours.)*

The result, $\phi_{message}$*, is to be encoded in the latitude field of the Airborne Position Message using the CPR algorithm described in Appendix A, §A.1.7.*

Note: *The amount of compensation performed by the ADS-B Transmitting Subsystem,* Δt*, is required to differ from* $t_{message} - t_{interface}$ *by not more than 100 ms. Acceptable means for accomplishing this include appropriately updating the position registers at sufficient rates, or extrapolating directly to a pre-computed time of transmission*

Note: *In order not to introduce excessive error in the estimated latitude,* $\phi_{message}$*, the latency,* $t_{interface} - t_{fix}$*, in the delivery of PVT data from the navigation data source should not be excessive.*

ADS-B Airborne Position Messages may alternatively implement estimation techniques such as alpha-beta trackers or Kalman filters to satisfy the intent of the 100 millisecond position requirement. Such techniques provide the capability to decouple the position computation from the message transmission timing provided that the timing of the sampled data and the output rate of the estimator are sufficient to satisfy the 100 millisecond requirement.

An acceptable method of implementing the position computation is to perform the extrapolation directly to an pre-computed time of transmission. However,

transponder based systems must also meet the Ground-Initiated Comm-B (GICB) register update timing performance so that periodic update of position data registers is necessary.

Note: *Appendix A 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 GICB service. 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-181D. Periodic loading of data into Register numbers 05 and 06 for airborne and surface position data is necessary to meet the TOA timing requirements between GICB register data and Extended Squitter Position Messages.*

For Mode S transponder based transmitting systems, the position register **shall** be reloaded 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.