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GNSS-BASED PRECISION APPROACH LOCAL AREA AUGMENTATION SYSTEM (LAAS) SIGNAL-IN-SPACE INTERFACE CONTROL DOCUMENT (ICD)

November 28, 2001
RTCA/DO-246B
Supersedes DO-246A

Prepared by SC-159

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FOREWORD

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1 PURPOSE AND SCOPE

1.1 Introduction

This Interface Control Document (ICD) defines the Signal-in-Space for the GNSS-based Local Area Augmentation System (LAAS) that supports Category I Precision Approach and the differential positioning service. The LAAS has global application as a Ground-Based Augmentation System (GBAS) to the Global Navigation Satellite System (GNSS). The content of this ICD has been harmonized with standards being developed by the International Civil Aviation Organization (ICAO) and The European Organization for Civil Aviation Equipment (EUROCAE) as of the approval of this document. This document should be useful to equipment designers, installers, manufacturers, service providers, and LAAS users.

Figure 1-1 shows the three required components of the LAAS system, specifically: the GNSS subsystem, the airborne subsystem and the ground subsystem. In addition to these three subsystems, additional components are required to maintain the operations of the LAAS (e.g., the GPS control segment, GLONASS control segment, WAAS/SBAS infrastructure), however, these components of the GNSS are not considered to be part of the LAAS for the purpose of this ICD.

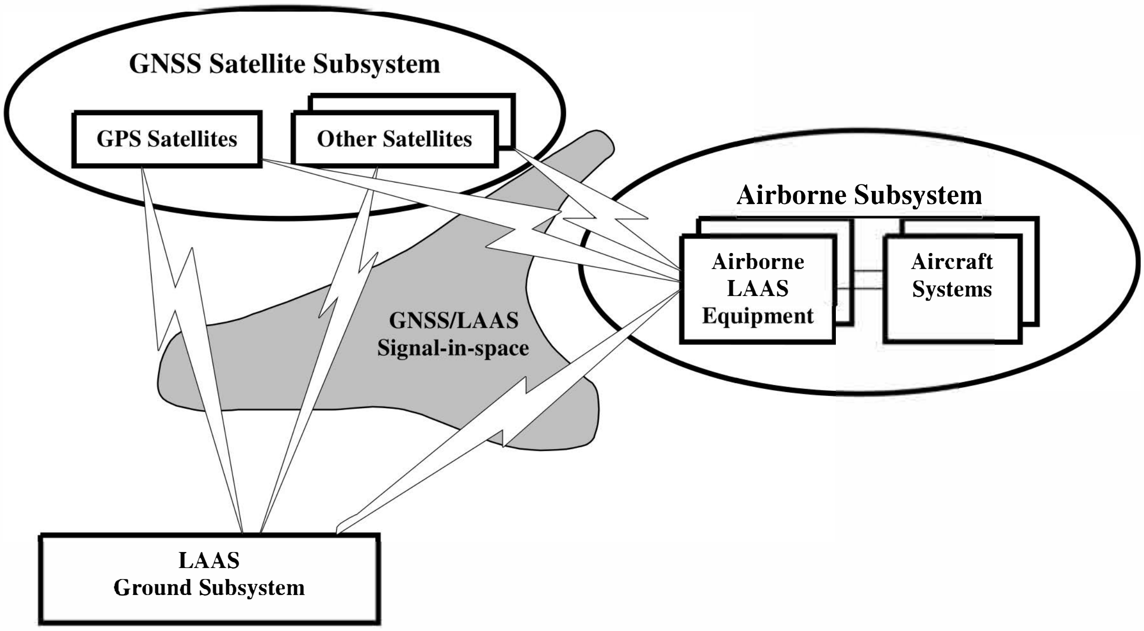

Figure 1-1 GNSS Based Local Area Augmentation System

The GNSS/LAAS Signal-in-Space is composed of four signals:

a. the navigation signal transmitted from the GNSS subsystem to the ground subsystems,

b. the navigation signal transmitted from the GNSS subsystem to the airborne subsystem,

c. the VHF Data Broadcast (VDB) transmitted from the ground subsystem to the airborne subsystem, and

d. the ranging broadcast transmitted from the ground subsystem to the airborne subsystem.

1.2 LAAS System Interface Description

The LAAS system operates using four interfaces shown in Figure 1-2. There are three unique interfaces that are defined in this ICD. The satellite ranging interface (Interfaces I and II) is the GNSS Ranging source interface. The definition of this interface already exists for GNSS in the form of: the ICD-GPS-200C, Navstar GPS Space Segment/Navigation User Interfaces and the WAAS Signal Specification (Appendix A of RTCA DO-229()), which define the nominal signal characteristics and performance of the GNSS satellites.

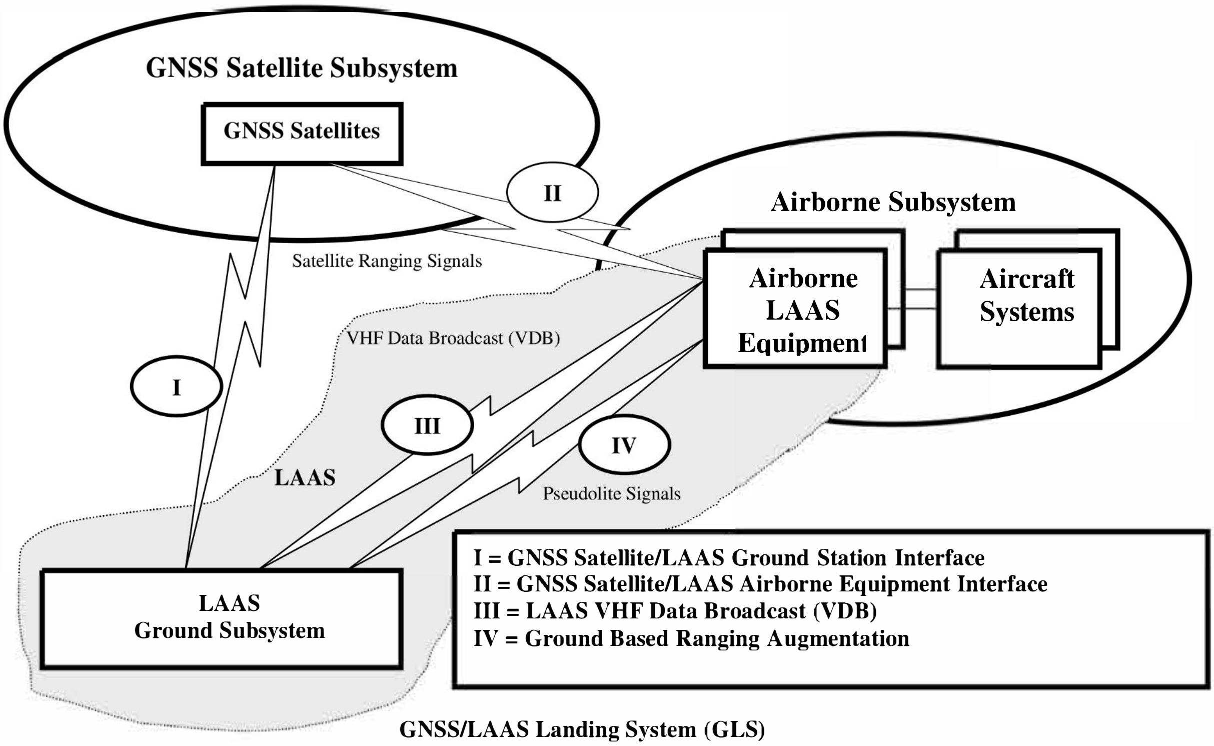

Figure 1-2 LAAS Signal-in-Space Interface Diagram

Performance above and beyond the minimum guaranteed by the GPS SPS Performance Standard is ensured through signal quality monitoring at the LAAS ground station. Several LAAS specific ranging source signal performance requirements have been identified to fully characterize anomalous ranging source conditions, which are not naturally corrected by the differential operation of the LAAS.

The third interface (Interface III) is the LAAS Ground Station/Airborne Equipment Interface, also referred to as the VHF Data Broadcast (VDB). Section 2.0 defines both the physical layer and the application data layer of the VDB. The physical layer includes a specification of the transmission band and modulation format. The application data includes information such as the differential correction information, the integrity data, the Final Approach Segment (FAS) definition data, and the ground station location data.

The fourth interface (Interface IV) is the ground based ranging source (GBRS) augmentation to airborne LAAS equipment. Appendix D of this document defines the proposed Signal-in-Space characteristics of the proposed GBRS (Airport Pseudolite - APL), which may be required to increase the LAAS navigation system availability to support CAT II&III operations. Appendix D includes information, which identifies the ranging performance of the LAAS signal provided by the ranging signal and measurement data for Interface IV. Appendix E provides the proposed pseudorandom pulse sequence used by the

GBRS and Appendix F provides the preliminary definition of the LAAS message format required to use a GBRS.

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2 DATA BROADCAST DEFINITION

This section describes the Signal-in-Space for the LAAS VHF Data Broadcast (VDB). The broadcast is a Time Division Multiple Access (TDMA), VHF data broadcast which complies with the physical layer of the ISO stack protocol described in ICAO Document AMCP/3-R/8A (VHF Digital Link Manual). The VDB link layer is different than VDL Mode 2. The data broadcast definition includes the data broadcast characteristics, data definition, broadcast timing, message format, and RF signal format.

2.1 RF Transmission Characteristics

2.1.1 Symbol Rate

The symbol rate of the LAAS data broadcast is 10,500 symbols/sec ±0.005%. Each symbol defines one of eight states (3 bits) resulting in a nominal bit rate of 31,500 bits/sec.

2.1.2 Emission Designator

The Federal Communications Commission (FCC) emission designator of this modulation technique is 14K0G7DET.

2.1.3 Field Strength

The FAA-specified LAAS signal has a minimum field strength of 215 microvolts per meter and a maximum of 0.350 volts per meter with a horizontal polarization and a minimum field strength of 136 microvolts per meter and a maximum of 0.221 volts per meter with a vertical polarization within the coverage region.

The VDB field strength measurement is averaged over the period of the synchronization and ambiguity resolution segment in the training sequence of the VDB message.

Notes:

1. *The ICAO Annex 10 Standards and Recommended Practices (SARPs) for GBAS allow for ground stations that transmit only a horizontally polarized signal, meeting the horizontal field strength requirements specified above. A ground facility that only broadcasts the horizontally polarized signal will be designated as a GBAS/H facility, while one that broadcasts the elliptically polarized signal will be designated as a GBAS/E facility. The SARPs GBAS/E vertical field strength requirements are as specified above. The SARPs recommend that an elliptically polarized signal be broadcast whenever practical.*
2. *The RTCA DO-245A provides further information and the nominal Link Budget.*
3. *The broadcast power of an installed VDB is constrained by many factors, only one of which is the desired field strength in the defined coverage region. Other constraints include adjacent and co-channel interference to neighboring systems and the VDB receiver sensitivity. The link budget for the minimum field strength is based on a distance of 23 nmi from the transmitting antenna, and the maximum field strength is based on a distance of 200 meters from the transmitting antenna.*

2.1.4 Spectral Characteristics

2.1.4.1 Carrier Frequencies

The system is defined to be capable of operating on carrier frequencies within the range of 108.000 MHz to 117.975 MHz inclusive with 25.0 kHz centers.

Note: *In accordance with ICAO Annex 10, operational frequency assignments will be assigned on 25 kHz centers in the range from 108.025 MHz to 117.950 MHz inclusive.*

2.1.4.2 Unwanted Emissions

Unwanted emissions, including spurious and out-of-band emissions, are compliant with the levels shown in Table 2-1. The total power in any VDB harmonic or discrete signal will not be greater than –53dBm.

Table 2-1 Unwanted Emissions

Frequency	Relative unwanted emissions level over a 25 kHz band (note 2)	Maximum unwanted emissions level (note 1)
9 kHz to 150 kHz	-93 dBc (note 3)	-55 dBm / 1 kHz (note 3)
150 kHz to 30 MHz	-103 dBc (note 3)	-55 dBm / 10 kHz
30 MHz to 106.125 MHz	-115 dBc	-57 dBm / 100 kHz
106.425 MHz	-113 dBc	-55 dBm / 100 kHz
107.225 MHz	-105 dBc	-47 dBm / 100 kHz
107.625 MHz	-101.5 dBc	-53.5 dBm / 10 kHz
107.825 MHz	-88.5 dBc	-40.5 dBm / 10 kHz
107.925 MHz	-74 dBc	-36 dBm / 1 kHz
107.975 MHz	-65 dBc	-27 dBm / 1 kHz
118.000 MHz	-65 dBc	-27 dBm / 1 kHz
118.050 MHz	-74 dBc	-36 dBm / 1 kHz
118.150 MHz	-88.5 dBc	-40.5 dBm / 10 kHz
118.350 MHz	-101.5 dBc	-53.5 dBm / 10 kHz
118.750 MHz	-105 dBc	-47 dBm / 100 kHz
119.550 MHz	-113 dBc	-55 dBm / 100 kHz
119.850 MHz to 1 GHz	-115 dBc	-57 dBm / 100 kHz
1 GHz to 1.7 GHz	-115 dBc	-47 dBm / 1 MHz

Notes:

1. *If the authorized transmitter power exceeds 150 watts, then the relative unwanted emissions requirements and the maximum unwanted emission requirements both apply. This column indicates the bandwidth over which the maximum unwanted emission levels must be met.*

2. *Relative unwanted emission level requirements apply to a 25 kHz bandwidth. This will require the conversion of measurements taken over a bandwidth different from 25 kHz.*

3. *This value is driven by measurement limitations. Actual performance is expected to be better.*

4. *The relationship is linear between single adjacent points designated by the adjacent channels identified above.*

5. *Spurious emissions are defined in 47 CFR 1.XX as emissions on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emis-*

sions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

6. *For LAAS, the necessary bandwidth is defined to be the channel bandwidth of 25 kHz.*
7. *The FCC spurious requirement may not provide adequate protection of nearby aircraft or LAAS ground subsystem GPS receivers from harmful interference, especially VHF 14th harmonics. Depending upon the implementation, additional filtering, shielding and/or separation from GPS receivers in the same area may be required.*
8. *Out-of-band emissions are defined in 47 CFR 1.XX as emissions on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, excluding spurious emissions.*
9. *ITU-R Recommendation 329 contains requirements for digital transmissions.*

2.1.4.3 Adjacent Channel Emissions

The amount of power during transmission under all operating conditions when measured over a 25 kHz bandwidth centered on the ith adjacent channels does not exceed the values in Table 2-2.

Table 2-2 Power Transmitted in Adjacent Channels

Adjacent Channel #	Channel Offset (kHz)	Relative Power	Maximum Power
1st	25 kHz	-40 dBc	12 dBm
2nd	50 kHz	-65 dBc	-13 dBm
4th	100 kHz	-74 dBc	-22 dBm
8th	200 kHz	-88.5 dBc	-36.5 dBm
16th	400 kHz	-101.5 dBc	-49.5 dBm
32nd	800 kHz	-105 dBc	- 53 dBm
64th	1,600 kHz	-113 dBc	-61 dBm
76th and beyond	≥1900 kHz	-115 dBc	-63 dBm

Notes:

1. *The maximum power applies if the authorized transmitter power exceeds 150 W.*
2. *The relationship is linear between single adjacent points designated by the adjacent channels identified above.*

2.1.4.4 Adjacent Temporal Interference

Under all operating conditions, the peak power at any time outside of the assigned time slots, when measured over a 25 kHz bandwidth centered on the assigned frequency, does not exceed -105 dBc referenced to the average power in a VDB burst.

2.1.4.5 Carrier Frequency Stability

The carrier frequency of the data broadcast is maintained within ± 0.0002% (± 2 parts per million) of the assigned frequency during all operational periods and through all the operating environmental conditions of the ground transmitter.

2.1.5 Modulation

Binary data is assembled into symbols, each consisting of 3 consecutive bits. The end of the data is padded by one or two fill bits if necessary to form the last 3-bit symbol of the burst. Symbols are converted to differentially-encoded 8 phase shift keyed (D8PSK) carrier phase shifts ($\Delta\phi_k$) as shown in Table 2-3.

The carrier phase for the kth symbol (ϕ_k) is given by:

$$\phi_k = \phi_{k-1} + \Delta\phi_k$$

The transmitted signal is $H(e^{j(2\pi ft + \phi(t))})$, where $H(\bullet)$ is a raised cosine filter with $\alpha = 0.6$ as defined in Section 2.1.5.1.

Table 2-3 Data Encoding

Message Bits (Note)			**Symbol Phase Shift**
I_{3k-2}	I_{3k-1}	I_{3k}	$\Delta\phi_k$
0	0	0	0
0	0	1	$1\pi/4$
0	1	1	$2\pi/4$
0	1	0	$3\pi/4$
1	1	0	$4\pi/4$
1	1	1	$5\pi/4$
1	0	1	$6\pi/4$
1	0	0	$7\pi/4$

Note: *I_j is the j^{th} bit of the burst to be transmitted, where I_1 is the first bit of the training sequence. The values of $\Delta\phi_k$ represent counter clockwise rotations in the complex I-Q plane of Figure 2-1.*

D8PSK may be produced as shown in Figure 2-1 by combining two quadrature RF signals which are independently-suppressed-carrier amplitude-modulated by baseband filtered impulses. The baseband filters have a frequency response with the shape of a raised cosine with an excess bandwidth factor (α) equal to 0.6. This characteristic allows a high degree of suppression of adjacent channel energy, with performance dependent only upon hardware implementation of the modulating and amplification circuits.

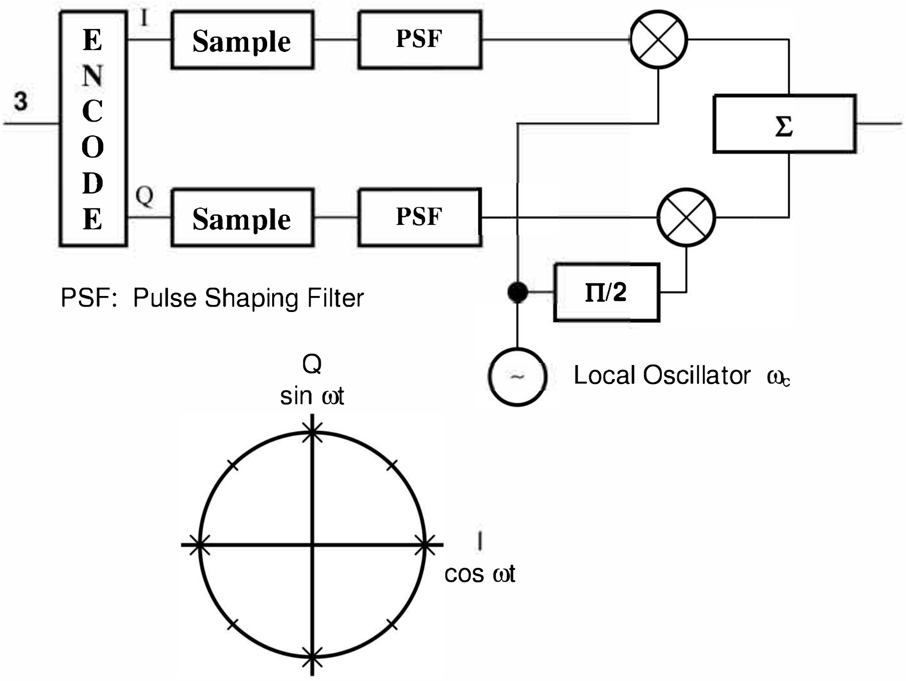

Figure 2-1 **D8PSK Data Modulator Example**

2.1.5.1 Pulse Shaping Filters

The output of differential phase encoder is filtered by a pulse shaping filter whose output, *s(t),* is described as follows:

$$s(t) = \sum_{k=-\infty}^{k=\infty} e^{j\phi_k} h(t-kT)$$

where:

h = the impulse response of the raised cosine filter

t = time

T = duration of each symbol (T=1/10500 second, approximately 95.2 µsec)

ϕ_k = as defined in Section 2.1.5

This pulse shaping filter has a nominal complex frequency response of a raised-cosine filter with $\alpha = 0.6$. The frequency response, *H(f)*, and the time response, *h(t)*, of the base band filters are as follows:

$$H(f)=\begin{cases} 1 & 0 \le f < \dfrac{1-\alpha}{2T} \\ \dfrac{1-\sin\left(\dfrac{\pi}{2\alpha}(2fT-1)\right)}{2}, & \dfrac{1-\alpha}{2T} \le f \le \dfrac{1+\alpha}{2T} \\ 0 & f > \dfrac{1+\alpha}{2T} \end{cases}$$

$$h(t) = \frac{\sin\left(\dfrac{\pi t}{T}\right)}{\dfrac{\pi t}{T}} \, \frac{\cos\left(\dfrac{\pi \alpha t}{T}\right)}{1-\left(\dfrac{2\alpha t}{T}\right)^2}$$

where:

f is the absolute value of the frequency offset from the channel center.

2.1.5.2 Error Vector Magnitude

The error vector magnitude of the transmitted signal is less than 6.5 percent RMS.

2.2 Broadcast Timing Structure

The high data rate of the physical layer offers more capacity than is required by any single LAAS ground station. As a result, spectrum efficiency is achieved through the use of a Time Division Multiple Access (TDMA) technique that partitions the total capacity offered by a single LAAS frequency assignment to individual proximate ground station VDB transmitters. The paragraphs of this subsection describe the time partitioning approach used for the LAAS VHF Data Broadcast.

2.2.1 TDMA Timing Structure

The TDMA timing structure is based on a two level hierarchy as shown in Figure 2-2. Each frame is 500 milliseconds in duration. There are two such frames contained in each one-second UTC epoch. The first of these frames starts at the beginning of the UTC epoch and the second starts 0.5 seconds after the beginning of the UTC epoch. The frame is time division multiplexed such that it consists of 8 individual VDB time slots (A - H) of 62.5 millisecond duration.

A VDB time slot establishes the incremental capacity resource that can be assigned to an individual LAAS ground transmission station. Within each time slot, a VDB burst can be transmitted. Bursts can be of variable length up to the maximum allowed within the slot. The following subsection details the timing budget and physical layer overhead required for the maximum length burst.

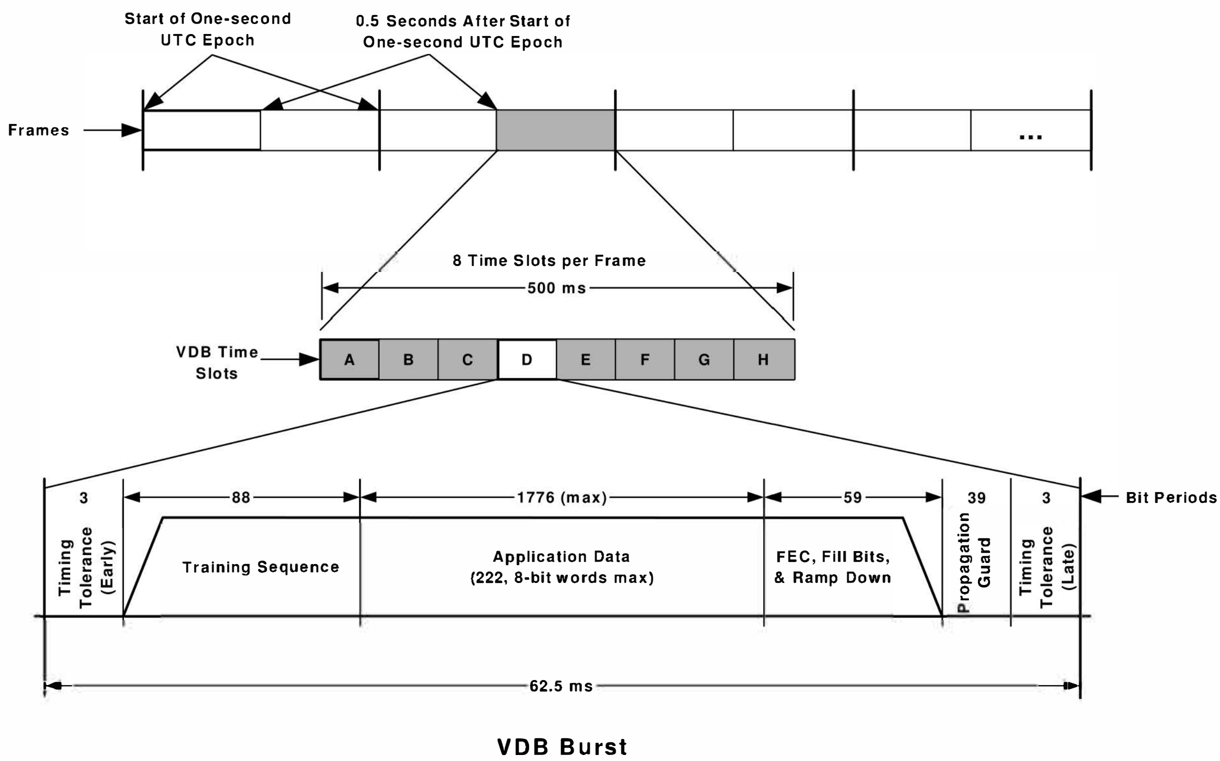

Figure 2-2 **TDMA Timing Structure**

2.2.2 Time Slot Initiation and Minimum Use

To initiate the use of a time slot, the VDB transmitter will broadcast a burst in that time slot in each of 5 consecutive frames. For each time slot in use, the VDB transmitter will broadcast a burst in at least one frame of every 5 consecutive frames.

2.2.3 Timing Budget For VDB Bursts

Each VDB burst is contained in a 62.5 millisecond time slot. At a rate of 10,500 symbols per second, each time slot contains 656.25 symbol periods.

The transmission of each burst begins 95.2 µs after the start of the time slot, with a total tolerance of ± 95.2 µs. The transmitter power ramps up to 90% of the steady-state power level within two symbol periods (≈ 190.5 µs) after the beginning of the burst, and stabilizes at the steady-state power within five symbol periods (≈ 476.2 µs) after the beginning of the burst. After transmission of the final information symbol of a burst, the transmitter output power level decreases to at least 30 dB below the steady-state power within 285.7 µs. A signal propagation guard time of 1261.9 µs at the end of each slot protects a one way propagation range of approximately 200 nmi. Table 2-4 shows the timing budget for a VDB burst. The start of the synchronization and ambiguity resolution portion of the burst transmitted with horizontal polarization (HPOL) will occur within 10 µs of the start of the burst transmitted with vertical polarization (VPOL), as received at the aircraft.

Table 2-4 Burst Timing

Event	Nominal Event Duration	Nominal Percentage of Steady-State Power
Ramp up	190.5 µs	0% to 90%
Transmitter Power Stabilization	285.7 µs	90% to 100%
Synchronization & Ambiguity Resolution	1523.8 µs	100%
Transmission of Scrambled Data	58761.9 µs	100%
Ramp down	285.7 µs (Note)	100% to 0%

Note: *Event duration indicated for transmission of scrambled data is for the maximum application data length of 1776 bits and two fill bits. The end of the burst occurs within 285.7 µs after the last symbol of the scrambled data.*

2.3 Burst Data Content

Each burst consists of the data elements shown in Table 2-5. The maximum burst duration is 1912 useful bits (239 bytes). Since the communications structure is based on an 88 bit training sequence and a 48-bit application FEC, up to1776 bits (222 bytes) can be used for application data.

As depicted in Figure 2-3, the encoding of the messages follows the sequence: application data formatting, training sequence FEC generation, application FEC generation, and bit scrambling.

Table 2-5 Burst Data Content

Element	Data Content	Number of Bits
Power Stabilization	Section 2.3.1.1	15
Synchronization & ambiguity resolution	Section 2.3.1.2	48
Scrambled Data:		
Station slot identifier (SSID)	Section 2.3.1.3	3
Transmission Length	Section 2.3.1.4	17
Training Sequence FEC	Section 2.3.1.5	5
Application Data	Section 2.3.2	Up to 1776
Application FEC	Section 2.3.3	48
Fill Bits (Note)	Section 2.1.5	0 to 2

Note: *Up to 2 fill bits are added as required for transmission of whole symbols. The number of fill bits varies depending on the number of bits in the application data. Data scrambling of the fill bits is optional and the set value of the fill bits is optional. The fill bits are not part of the application data used by the aircraft receiver.*

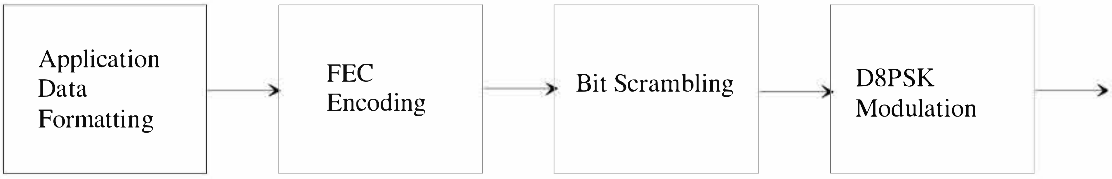

Figure 2-3 Message Encoding

2.3.1 Training Sequence

The data broadcast message begins with a 5-segment demodulator training sequences as shown in Table 2-6. The training sequence allows proper demodulation of the message by the airborne subsystem.

Table 2-6 Training Sequence Format

Segment Sequence	Training Sequence Description	Number of Bits
1	Power Stabilization	15
2	Synchronization & Ambiguity Resolution	48
3	Station Slot Identifier (SSID)	3
4	Transmission Length	17
5	Training Sequence FEC	5
	TOTAL	88

2.3.1.1 Power Stabilization

The first segment of the training sequence is the 15-bit Power Stabilization field, coded as all zeros. The transmitted signal reaches at least 90% of the steady-state power level within two symbols to allow the airborne receiver's automatic gain control (AGC) at least three symbols settling time.

2.3.1.2 Synchronization and Ambiguity Resolution

The second segment of the training sequence is the 48-bit Synchronization and Ambiguity Resolution field consisting of the following sequence:

010 001 111 101 111 110 001 100 011 101 100 000 011 110 010 000

with the right-most bit (LSB) transmitted first.

Note: *This sequence was designed to have good auto-correlation properties and to facilitate estimation of the center frequency.*

2.3.1.3 Station Slot Identifier

The third segment of the training sequence is the 3-bit Station Slot Identifier (SSID). The SSID is a numeric value from 0 to 7, corresponding to the letter designation (A through H) of the first time slot assigned to a particular ground reference station, where slot A = 0 and slot H = 7. All messages in all time slots employed by a particular ground station use the same SSID. The SSID is transmitted LSB first.

Notes: ***1.*** *The purpose of transmitting the SSID is to provide a low overhead way for the airborne receiver to decide whether to process the rest of the burst data. This provides the avionics manufacturer the opportunity to reduce unnecessary traffic on the data bus.*

2. *SSID Example*

GBAS ID	*Time Slots Assigned*	*SSID*
GYUL	*A,C*	*0*
GYMX	*D,F*	*3*
GYSF	*G*	*6*

3. *Because SSID values are defined directly from time slot assignments, there is no requirement for Spectrum Management authorities to separately manage the assignment of SSID. It is not intended that the SSID be required in an airborne database.*

4. *Because the assignment of slots is not guaranteed to be unique within radio range, an airborne user may receive messages from more than one ground station with the same SSID. All messages from a single ground station will have the same SSID; however, all messages received with the same SSID are not necessarily from the same ground station. Therefore, the airborne receiver must also examine the GBAS ID in the field of every message header to determine which ground station produced the message.*

2.3.1.4 Transmission Length

The fourth segment of the training sequence is the 17-bit Transmission Length. This field indicates the total number of bits in the Application Data and Application FEC. This allows the airborne receiver to determine the length of the Reed-Solomon block. The order of transmission is from least significant bit (LSB) to most significant bit (MSB).

Note: *Although no transmission length exceeds 1824 bits the full 17 bits are included to be consistent with the ICAO Document AMCP/3-R/8A (VHF Digital Link Manual).*

2.3.1.5 Training Sequence FEC

The fifth segment of the training sequence is the Training Sequence FEC. A (25,20) block code is computed over the SSID and Transmission Length segments using the following equation.

$$[P_{1,} ..., P_5] = [SSID_1, ,SSID_3, TL_{1, ...,} TL_{17}]\ H^T$$

where:

P_n is the n^{th} bit of the training sequence FEC (P_1 is transmitted first)

SSID is the n^{th} bit of the Station slot identifier ($SSID_1$=LSB)

TL_n is the n^{th} bit of the transmission length (TL_1=LSB)

H^T is the matrix H transpose function and

H is the parity matrix defined below:

$$H = \begin{matrix} 0&0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1&1&0&0&0&0&1&1&1&1&1&1&1&1 \\ 1&1&0&0&0&1&1&1&0&0&1&1&0&0&0&0&1&1&1&1 \\ 1&1&0&1&1&0&1&1&0&1&0&1&0&0&1&1&0&0&1&1 \\ 0&1&1&0&1&0&0&1&1&1&1&0&0&1&0&1&0&1&0&1 \end{matrix}$$

Note: *This code is capable of correcting all single bit errors and detecting 75 of 380 possible double bit errors.*

2.3.2 Application Data

The application data consists of one or more message blocks, as defined in Section 2.3.5. The message blocks are mapped directly into the Application Data portion of the VDB burst with no additional overhead of intervening layers. Broadcasting of messages across multiple bursts is not supported; each message must be completely contained within a single burst. The order of transmission for the application data is LSB first followed by the higher order bits of each field.

2.3.3 Application FEC

The application FEC coding is accomplished by means of a systematic fixed length Reed-Solomon (255,249) 2^{8}-ary code capable of correcting up to three code word symbol errors. The field defining primitive polynomial of the code is as follows:

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

The generator polynomial is given by:

$$g(x) = \prod_{i=120}^{125}\left(x - \alpha^i\right) = x^6 + \alpha^{176}x^5 + \alpha^{186}x^4 + \alpha^{244}x^3 + \alpha^{176}x^2 + \alpha^{156}x + \alpha^{225}$$

where:

α is a root of p(x) used for construction of the Galois Field of size 2^8; GF(256), and α^i is the i^{th} primitive element in GF(256).

Virtual fill bits set to zero will be temporarily appended to the application data as necessary to create an input stream to the application FEC encoder and decoder of 1992 bits (249 bytes). These virtual fill bits are not transferred to the bit scrambler or transmitted.

In generating the application FEC, the data to be encoded, m(x), will be grouped into 8 bit Reed- Solomon symbols. The data m(x) is defined by:

$$m(x) = a_{248}x^{248} + a_{247}x^{247} + \ldots + a_{248-length+1}x^{248-length+1} + a_{248-length}x^{248-length} + \ldots + a_1x + a_0$$

where:

length represents the number of 8-bit bytes in the application data block

a_{248} represents the Message Block Identifier (MBI), with the rightmost bit defined as the LSB and the first bit of the application data sent to the bit scrambler

$a_{248\text{-length}+1}$ represents the last byte of the message block CRC, with the leftmost bit defined as the MSB and the last bit of the application data sent to the bit scrambler

$a_{248\text{-length}}$, …, a_1, a_0 are the virtual fill bits (if any)

The six Reed-Solomon check symbols (b_i) are defined as the coefficients of the remainder resulting from dividing the message polynomial $x^6m(x)$ by the generator polynomial g(x):

$$b(x) = \sum_{i=0}^{5} b_i x^i = b_5x^5 + b_4x^4 + b_3x^3 + b_2x^2 + b_1x + b_0 = \left[x^6 m(x)\right] \bmod g(x)$$

These 8-bit Reed-Solomon check symbols are appended to the application data.

The Application FEC is ordered such that the first Application FEC bit transferred to the bit scrambler is the MSB of the 6^{th} 8-bit code word, b_0, generated by the FEC encoder, and the last Application FEC bit transferred to the bit scrambler is the LSB of the 1^{st} code word, b_5.

Note: The order of the transmitted 8-bit Reed-Solomon check symbols of the appended application FEC differs from VDL-2.

2.3.4 Bit Scrambling

In order to aid clock recovery, a pseudonoise (PN) scrambler with a 15-stage generator register are exclusive OR'ed with the transmitted data stream starting with the station slot identifier and ending with the application FEC. Bit scrambling of any fill bits is optional, and the set value of the fill bits is optional.

Note: The fill bits are not used by the aircraft receiver, so their value has no impact on system performance.

The concept of a PN scrambler is shown in Figure 2-4 (the descrambler is identical). The polynomial for the register of the scrambler is $1 + X + X^{15}$. The register content is rotated at the rate of one shift per bit. The initial status of the register, prior to the first station slot identifier bit of each burst, is 1101 0010 1011 001 with the leftmost bit in the first stage of the register. The first output bit of the scrambler/descrambler is sampled prior to the first register shift.

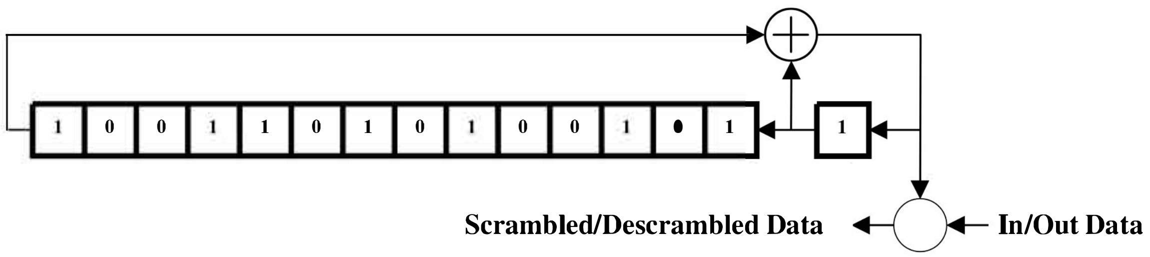

Figure 2-4 Bit Scrambler/Descrambler

2.3.5 Application Layer

The application layer of the ISO Stack Protocol for messages within the VHF data broadcast is described in the following paragraphs. Table 2-7 displays the general construction of a LAAS Message Block. All signed parameters are 2's complement numbers except as noted.

Table 2-7 Format of a LAAS Message Block

Message Block	Bits	Bytes
Message Block Header	48	6
Message	up to 1696	up to 212
Message Block CRC	32	4

2.3.6 Message Block Header

The Message Block Header contains information relevant to every LAAS transmission. Table 2-8 diagrams a Message Block Header. It consists of a Message Block Identifier (MBI) and a twenty-four bit GBAS ID, which identifies the LAAS reference station.

These fields are followed by an eight-bit message type field and an eight-bit message length field.

Table 2-8 Format of Message Block Header

Message Header	Bits	Bytes
Message Block Identifier	8	1
GBAS ID	24	3
Message Type	8	1
Message Length	8	1

Message Block Identifier: The 8-bit message block identifier (MBI) denotes the start of a message block, and indicates the operating mode of the LAAS message block.

"1010 1010" = a normal LAAS message

"1111 1111" = a test LAAS message

All other codings indicate non-LAAS message formats not supported by this ICD.

GBAS ID: a four-character (24-bit) alphanumeric field that identifies the ground station broadcasting the message. Each character is represented by bits b_1 through b_6 of its International Alphabet #5 representation (reference section 2.4.2), with bit b_1 transmitted first. Only capital letters, numbers, and "space" are permitted. The right-most character is transmitted first. For a 3-character ID, the right- most (first transmitted) character is "space".

Message Type: an 8-bit numeric label identifying the contents of the message.

Message Length: The length, in bytes, of the Message Block including the message block header, the message and the message block CRC.

2.3.6.1 Test Mode

When the station is operating in a mode where the SIS does not conform with the certification requirements of the station or the definition in this ICD, the Message Block Identifier is set to "1111 1111".

Note: *Individual message transmissions can be set invalid by setting the Message Block Identifier to "1111 1111" for that message.*

2.3.7 Cyclic Redundancy Check

A 32-bit cyclic redundancy check (CRC) concludes each message block in order to ensure message integrity.

The generator polynomial G(x) for the message block CRC is:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

The CRC information field, M(x) is:

$$M(x) = \sum_{i=1}^{n} m_i x^{n-i} = m_1 x^{n-1} + m_2 x^{n-2} + \ldots + m_n x^0$$

M(x) is formed from the 48-bit LAAS message block header and all bits of the variable-length Message, excluding the CRC. Bits are arranged in the order transmitted, such that m_1 corresponds to the first transmitted bit of the message block header, and m_n corresponds to the last transmitted bit of the (n-48) message bits.

The CRC is ordered such that r_1 is the first bit transmitted and r_{32} is the last bit transmitted.

Further details of the CRC implementation are provided in Appendix A.

2.4 LAAS Messages

2.4.1 Message Types and Broadcast Rates

The range of the 8-bit message type field of the message block header allows for up to 256 message types. Eight of the 256 message types have been allocated. Message Types 1, 2 and 4 are required, while Message Type 5 is optional. It is intended that unique military information be communicated via Message Type 7 and that experimental, private-use, and proprietary messages be communicated via Message Type 8.

Table 2-9 lists the allocated message types, and the required broadcast rates to support Category I precision approach and the differential positioning service.

Message Types 0, 3, 6 and 9 through 255 are reserved for future operations. It is intended that proposed definitions of the reserved messages be coordinated through the RTCA. It is also intended that these messages be assigned for common-use aviation applications only and be defined in this ICD.

Table 2-9 LAAS VHF Data Broadcast (VDB) Messages and Broadcast Rates

Message Type	Message Name	Minimum Broadcast Rate	Maximum Broadcast Rate
1	Differential Corrections	For each measurement type: All measurement blocks, once per frame (Note 1)	For each measurement type: All measurement blocks, once per slot (Note 1)
2	GBAS Related Data	Once per 20 consecutive frames	Once per frame
3	Reserved for GBRS (APL) Acquisition Data	-	-
4	Final Approach Segment (FAS) Construction Data	All FAS blocks once per 20 consecutive frames (Note 2)	All FAS blocks once per frame (Note 2)
5	Ranging Source Availability (optional)	All impacted sources once per 20 consecutive frames	All impacted sources once per 5 consecutive frames
6	Reserved For Carrier Corrections	-	-
7	Reserved for Military	-	-
8	Reserved for Test	-	-

Notes:

1. *Each Type 1 message or linked Type 1 message pair broadcast in a given frame includes the complete set of measurement blocks for its measurement type.*
2. *If no final approach segments (FAS) are currently being supported, then it is not necessary to transmit Type 4 messages.*

2.4.2 Data Format

The order of the application data is reflected in the order of the fields in each Message Type and FAS table from top to bottom.

Bits identified as spare have no defined use and are coded as zeros. In the future, spare bits in a message may be defined to incorporate additional parameters at which point these bits are no longer spare. Spare bits should be ignored except for the purposes of CRC and FEC processing.

Unless otherwise specified, all signed numbers are coded in two's complement format.

Certain LAAS message fields contain alphanumeric data coded using a subset of International Alphabet No. 5 (IA-5).

Table 2-10 shows the coding for this subset of IA-5.

Table 2-10 Subset of International Alphabet No. 5

Binary Code (Note 1)	**Character**	**Binary Code** (Note 1)	**Character**	**Binary Code** (Note 1)	**Character**
000000		010000	P	110000	0 (Note 3)
000001	A	010001	Q	110001	1 (Note 3)
000010	B	010010	R	110010	2 (Note 3)
000011	C	010011	S	110011	3 (Note 3)
000100	D	010100	T	110100	4 (Note 3)
000101	E	010101	U	110101	5 (Note 3)
000110	F	010110	V	110110	6 (Note 3)
000111	G	010111	W	110111	7 (Note 3)
001000	H	011000	X	111000	8 (Note 3)
001001	I (Note 3)	011001	Y	111001	9 (Note 3)
001010	J	011010	Z	111010 to 111111	(Note 2)
001011	K	011011 to 011111	(Note 2)		
001100	L				
001101	M	100000	"space"		
001110	N	100001 to 101111	(Note 2)		
001111	O (Note 3)				

Notes:

1. *Binary code values represent IA-5 bits b_1 through b_6, with b_1 as the right-most bit. IA-5 bits b_7 and b_8 are not used in the LAAS application.*
2. *Values not used for LAAS message fields.*
3. *Values not used for 5-bit Route Indicator field.*
4. *For the coding of the route indicator in the FAS data block, only bits b_1 through b_5 are used.*

2.4.3 Message Type 1 — Differential Corrections

2.4.3.1 Message Description

Message Type 1 provides the differential correction data for individual GNSS ranging sources. The message contains three sections: message information (time of validity, additional message flag, number of measurements and the measurement type), low frequency correction information (ephemeris decorrelation parameter, ranging source ephemeris CRC and ranging source availability duration information) and the ranging source data measurement blocks. The message format is defined in Table 2-11.

Table 2-11 Format of Message Type 1

Data Content	Bits Used	Range of Values	Resolution
Modified Z-count	14	0 – 1199.9 sec	0.1 sec
Additional Message Flag	2	0 – 3	1
Number of Measurements	5	0 – 18	1
Measurement Type	3	0 – 7	1
Ephemeris Decorrelation Parameter (Notes 2, 5)	8	$0 – 1.275 \times 10^{-3}$	5×10^{-6} m/m
Ephemeris CRC (Notes 2, 5)	16	-	-
Source Availability Duration (Notes 4, 5)	8	0 – 2540 sec	10 sec
For N Measurement Blocks:			
Ranging Source ID	8	1 – 255	1
Issue of Data (IOD)	8	0 – 255	1
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s
σ_{pr_gnd} (Note 3)	8	0 - 5.08 m	0.02 m
B_1 (Note 1)	8	±6.35 m	0.05 m
B_2 (Note 1)	8	±6.35 m	0.05 m
B_3 (Note 1)	8	±6.35 m	0.05 m
B_4 (Note 1)	8	±6.35 m	0.05 m

Note 1: *1000 0000 indicates the measurement is not available.*

Note 2: *For SBAS satellites and GBRSs, the parameter is set to all 0's.*

Note 3: *1111 1111 indicates the source is invalid.*

Note 4: *1111 1111 indicates that value is not computed and should not be used.*

Note 5: *Parameter is associated with the first transmitted measurement block.*

Each Type 1 Message includes low frequency data for one ranging source consisting of the Ephemeris Decorrelation, Ephemeris CRC and Source Availability Duration parameters. The low frequency data corresponds to the first ranging source in the message. Except during an ephemeris change, the ground reference station sequences the first ranging source so that the low frequency data for each GPS ranging source is transmitted at least once every 10 seconds. During an ephemeris change, the low frequency data for each GPS ranging source are transmitted at least once every 27 seconds.

The ground reference station will continuously receive the Ephemeris data from each GPS satellite, but will not use the new Ephemeris data until it has been received continuously for at least two minutes. The new Ephemeris data becomes the basis for the corrections after two and before three minutes have passed. Pseudorange corrections based on the new Ephemeris data will be first transmitted in the Type 1 message in the same message where the "Ephemeris CRC" and the IOD indicate a new data set. Each time the "Ephemeris CRC" changes, the ground reference station sequences the order of the transmission so that the "Ephemeris CRC" is transmitted in all Type 1 messages containing a measurement block for that satellite, for three consecutive frames as shown in the example in Figure 2-5.

For SBAS satellites, new Ephemeris data (SBAS Type 9) will be used immediately upon receipt by the ground reference station.

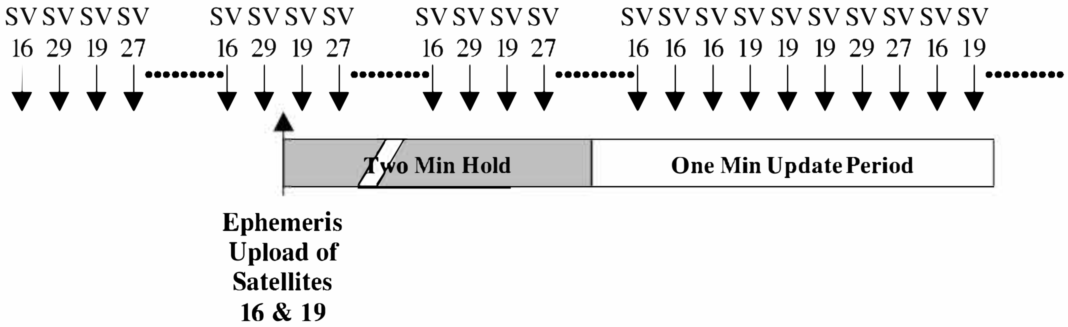

Figure 2-5 Low Frequency Correction Transmission (Ephemeris CRC)

The correction data applies only to a ranging measurement for which the IOD broadcast by the ranging source is identical to the corresponding IOD in the differential correction message, and for which the CRC calculated from the ranging source ephemeris is identical to the most recent ephemeris CRC for that ranging source in a differential correction message.

Note 6: *Sequencing SBAS satellites and GBRSs through the first ranging source measurement block in Message Type 1 is optional.*

2.4.3.2 Message Type 1 Parameters

Additional Message Flag: identifies whether the set of corrections (measurement blocks) in a single frame for a particular measurement type is contained in a single Type 1 message or a linked pair of messages. The two messages of a linked pair will have the same Modified Z-count, and each of the two messages will contain at least one measurement block.

0 = All measurement blocks for a particular measurement type are contained in a single Message Type 1.

1 = This is the first transmitted message of a linked pair of Type 1 Messages that together contain the set of all measurement blocks for a particular measurement type.

2 = Reserved.

3 = This is the second transmitted message of a linked pair of Type 1 Messages that together contain the set of all measurement blocks for a particular measurement type.

Note 1: *When a linked pair of Type 1 messages is used for a particular measurement type, the first message will indicate the number of corrections in the first message and the second message will indicate the number of corrections in the* *second message. Each message will include the low frequency data for the first ranging source in its own message.*

B1 through B4: are the differences between the broadcast pseudorange corrections and the corrections calculated by excluding the specific reference receiver measurement, as illustrated in Figure 2-6. A coding of “1000 0000” indicates that the associated LAAS reference receiver is not present, or that its measurement was not used to compute the pseudorange correction. At least two valid B values will be provided with each pseudorange correction.

Note 2: *B1 through B4 are the estimates of the error resulting from specific reference receiver measurements on the pseudorange corrections.*

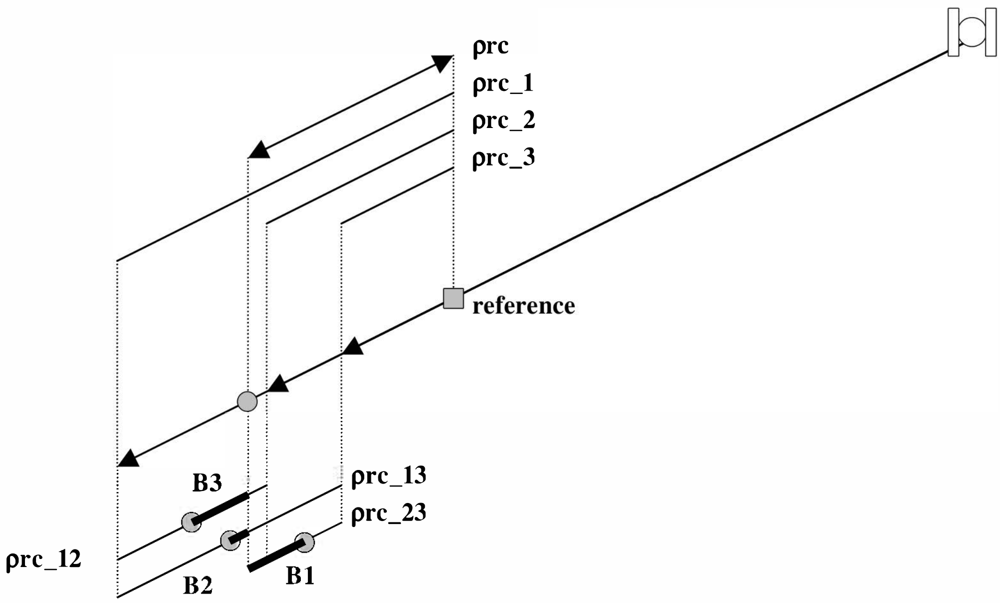

Figure 2-6 Illustration of Error Estimate (B) Parameters

Ephemeris CRC: is the 16-bit cyclic redundancy check (CRC) computed on the satellite ephemeris data set in order to ensure ranging source position integrity.

The generator polynomial G(x) for the ephemeris CRC is:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The CRC information field, M(x), for a given ranging source is:

$$M(x) = \sum_{i=1}^{n} m_i x^{n-i} = m_1 x^{n-1} + m_2 x^{n-2} + \ldots + m_n x^0$$

For a GPS satellite, M(x), is of length n=576 bits. M(x) for a GPS satellite is calculated using the first 24 bits from each of Words 3 through 10 of Subframes 1, 2 and 3 of the data transmission from that satellite, ANDed with the GPS satellite ephemeris mask of Table 2-12. After the AND operation, M(x) is arranged in the order that bytes are transmitted by the GPS satellite, but with each byte ordered least-significant bit first, such that m_1 corresponds to bit 68 of Subframe 1 (LSB of Subframe 1, Word 3), and m_{576} corresponds to bit 287 of Subframe 3 (MSB of Subframe 3, Word 10).

For an SBAS satellite and GBRS, the ephemeris CRC is coded as all zeros.

The CRC is ordered such that r_1 is the first bit transmitted and r_{16} is the last bit transmitted.

Further details of CRC implementation are provided in Appendix A.

Table 2-12 GPS Satellite Ephemeris Mask

	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Subframe 1:							
Word 3	00000000	00000000	00000011	Word 4	00000000	00000000	00000000
Word 5	00000000	00000000	00000000	Word 6	00000000	00000000	00000000
Word 7	00000000	00000000	11111111	Word 8	11111111	11111111	11111111
Word 9	11111111	11111111	11111111	Word 10	11111111	11111111	11111100
Subframe 2:							
Word 3	11111111	11111111	11111111	Word 4	11111111	11111111	11111111
Word 5	11111111	11111111	11111111	Word 6	11111111	11111111	11111111
Word 7	11111111	11111111	11111111	Word 8	11111111	11111111	11111111
Word 9	11111111	11111111	11111111	Word 10	11111111	11111111	00000000
Subframe 3:							
Word 3	11111111	11111111	11111111	Word 4	11111111	11111111	11111111
Word 5	11111111	11111111	11111111	Word 6	11111111	11111111	11111111
Word 7	11111111	11111111	11111111	Word 8	11111111	11111111	11111111
Word 9	11111111	11111111	11111111	Word 10	11111111	11111111	11111100

Note 3: *The order of the Ephemeris Mask corresponds to order of bits transmitted from GPS satellites.*

Ephemeris Decorrelation Parameter (P): characterizes the impact of residual ephemeris errors due to decorrelation.

Note 4: *For ground systems that do not broadcast the additional data block 1 in the Type 2 message, this parameter is coded as all zeros.*

Issue of Data: is the IOD associated with the ephemeris data used to determine pseudo-range and range rate corrections. The IOD for GPS ranging sources is coded to match the GPS IODE parameter. A coding of "1111 1111" is used for SBAS ranging source.

Measurement Type: identifies the type of ranging signal from which the corrections have been computed:

0 = C/A code L1
1 = C/A code L2
2 = P(Y) code L1
3 = P(Y) code L2
4 – 7 = Reserved

Note 5: *Measurement type does not indicate the ranging source. The ranging source ID indicates the type of satellite.*

Modified Z-count: indicates the reference time for all message parameters in this message. The modified z-count correlates with GPS time, except that it resets on the hour (xx:00), twenty minutes past the hour (xx:20), and forty minutes past the hour (xx:40). For a given measurement type, all Type 1 messages transmitted in a given frame have the same modified z-count. The modified z-count for each measurement type advances each frame.

Number of Measurements: identifies the number of ranging source measurements in the message.

Pseudorange Correction: is defined as the correction to the ranging source SIS pseudorange. A differential pseudorange correction is the average of the corrections based on measurements from multiple ground reference receivers. The pseudorange corrections are based on carrier smoothed code pseudorange measurements. The Pseudorange Correction (PRC) is applicable at the time defined in the Type 1 message. The order of corrections is defined in Figure 2-7.

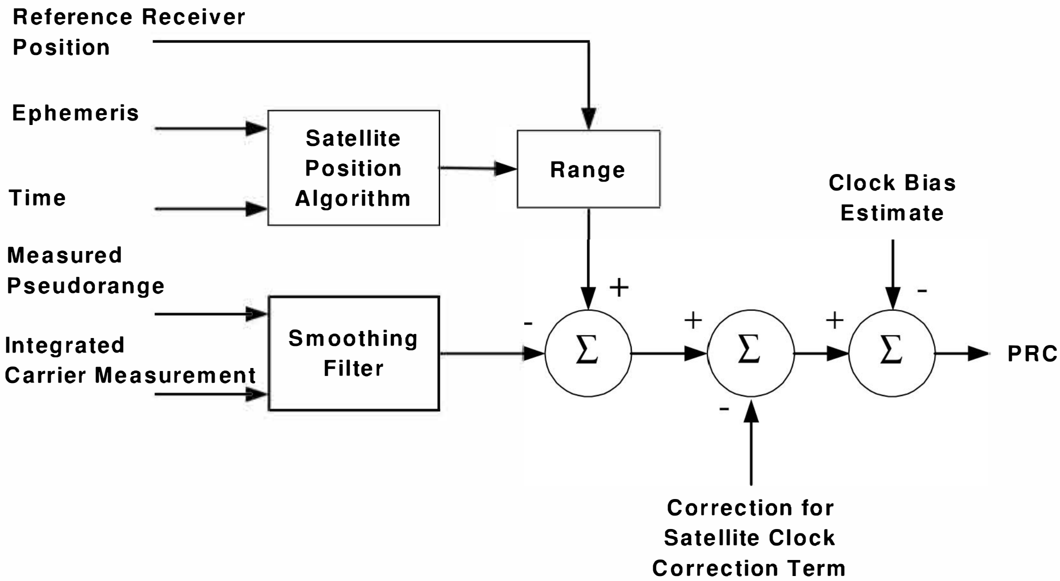

Figure 2-7 Pseudorange Correction Computation

Range Rate Correction: is the rate of change of the pseudorange correction. The Range Rate Correction (RRC) is multiplied by the age of the correction [determined from the current time (t) minus the time of applicability of the PRC determined from the modified z-count (t_{zcount})] and added to the PRC and the measured pseudorange (P_n). The satellite clock correction ($c^*(\Delta t_{sv})_{L1}$), including relativistic corrections, is then added to compute the corrected pseudorange measurement ($P_{corrected}$).

$$P_{corrected} = P_n + PRC + RRC^*(t - t_{zcount}) + TC + c^*(\Delta t_{sv})_{L1}$$

Note 6: *TC is the tropospheric correction at the user location calculated by the airborne receiver using the Refractivity Index and Scale Height parameter, where*

$$TC = N_R\, h_0 \frac{10^{-6}}{\sqrt{0.002 + \sin^2(\theta)}} \left(1 - e^{-\Delta h / h_0}\right)$$

where:

N_R = refractivity index from the Type 2 message

Δh= height of the aircraft above the GBAS reference point

θ = elevation angle of the satellite

h_0= tropospheric scale height from the Type 2 message.

Ranging Source ID: identifies the ranging source to which corrections and/or availability data are applicable.

1 to 36	=	a GPS satellite whose PRN is equal to the Ranging Source ID value.
37	=	reserved.
38 to 61	=	a GLONASS satellite whose slot is equal to the Ranging Source ID value plus 37.
62 to 119	=	reserved.
120 to 138	=	an SBAS satellite whose PRN is equal to the Ranging Source ID value.
139 to 255	=	reserved.

σ_{pr_gnd}: is the standard deviation of a normal distribution that bounds the SIS contribution to the error in the corrected pseudorange at the GBAS reference point. The normal distribution $N(0, \sigma^2_{pr\_gnd})$ bounds the error under the H_0 hypothesis. In addition, the normal distribution $N(B_j, M\sigma^2_{pr\_gnd}/(M\text{-}1))$ (where M is the number of valid measurements) bounds the error under the H_1 hypothesis for a fault in the j^{th} receiver measurement. A coding of "1111 1111" indicates that corrections for a ranging source have been identified as invalid by the ground system.

Source Availability Duration: the predicted duration for which corrections for the ranging source are expected to remain available, relative to the modified z-count for the first measurement block.

Coding:

"1111 1110" indicates that the duration is greater than or equal to 2540 seconds.

"1111 1111" indicates that the duration information is not provided by the ground facility.

2.4.4 Message Type 2 — GBAS Related Data

2.4.4.1 Message Description

Message Type 2 identifies the exact location for which the differential corrections provided by the ground augmentation system are referenced. The LAAS ground station reference point is defined in WGS-84 coordinates. The message also contains configuration data and data to compute a tropospheric correction. The message format is shown in Table 2-13.

Additional data blocks may be appended to the end of the Type 2 message. Currently there is only one additional data block defined. In the future other additional data blocks may be defined and appended to the end.

Table 2-13 Format of Message Type 2

Data Content	Bits Used	Range of Values	Resolution
Ground Station Reference Receivers	2	2 - 4	-
Ground Station Accuracy Designator	2	-	-
Spare	1	-	-
Ground Station Continuity/Integrity Designator	3	-	-
Local Magnetic Variation	11	± 180°	0.25°
Spare	5	-	-
$\sigma_{vert\_iono\_gradient}$	8	0 – 25.5 x 10^{-6} m/m	0.1 x 10^{-6} m/m
Refractivity Index	8	16 - 781	3
Scale Height	8	0 - 25500 m	100 m
Refractivity Uncertainty	8	0 – 255	1
Latitude	32	± 90.0°	0.0005 arcsec
Longitude	32	± 180.0°	0.0005 arcsec
Reference Point Height	24	± 83886.07 m	0.01 m
Additional data block 1 (if provided)			
Reference station data selector	8	0 to 48	1
Maximum use distance (D_{max})	8	2 to 510 km	2 km
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05
$K_{md\_e\_CAT1,GPS}$	8	0 to 12.75	0.05
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05
$K_{md\_e\_CAT1,GLONASS}$	8	0 to 12.75	0.05

2.4.4.2 Message Type 2 Parameters

Ground Station Accuracy Designator: is the letter designator indicating the minimum signal in space accuracy performance provided by the ground station as defined in RTCA/DO-245().

0 = Ground Subsystem has accuracy designation A

1 = Ground Subsystem has accuracy designation B

2 = Ground Subsystem has accuracy designation C

3 = Spare

Ground Station Continuity/Integrity Designator (GCID): numerical designator that indicates the operational status of GBAS.

0 = Reserved

1 = GCID 1

2 = GCID 2

3 = GCID 3

4 = GCID 4

5 = Reserved

6 = Reserved

7 = Unhealthy

Ground Station Reference Receivers: is the number of GNSS reference receivers installed in this system.

0 = Ground Station with 2 reference receivers installed

1 = Ground Station with 3 reference receivers installed

2 = Ground Station with 4 reference receivers installed

3 = Reserved

$K_{md\_e\_CAT1,GLONASS}$: is the multiplier for computation of the ephemeris error position bound for Category I precision approach derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite. For GBAS ground sub-systems that do not broadcast corrections for GLONASS ranging sources, this parameter is coded as all zeros.

$K_{md\_e\_CAT1,GPS}$: is the multiplier for computation of the ephemeris error position bound for Category I precision approach derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite. For GBAS ground sub-systems that do not broadcast corrections for GPS ranging sources, this parameter is coded as all zeros.

$K_{md\_e\_POS,GLONASS}$: is the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite. For GBAS ground sub-systems that do not broadcast corrections for GLONASS ranging sources or that do not provide positioning service, this parameter is coded as all zeros.

$K_{md\_e\_POS,GPS}$: is the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite. For GBAS ground sub-systems that do not broadcast corrections for GPS ranging sources or that do not provide the GBAS positioning service, this parameter is coded as all zeros.

Latitude: is the latitude of the ground station reference point and is defined in WGS-84 coordinates and transmitted in arc seconds. A positive value denotes North latitude; a negative value denotes South latitude.

Local Magnetic Variation: is the published local magnetic variation at the differential reference point. A positive value represents an east variation (clockwise from true north). A coding of "100 0000 0000" indicates that precision approach procedures provided by this ground station are published based on true bearing.

Longitude: is the longitude of the ground station reference point and is defined in WGS-84 coordinates and transmitted in arc seconds. A positive value denotes East longitude; a negative value denotes West longitude.

Maximum Use Distance: is the maximum distance from the GBAS reference point for which the integrity is assured.

0 = No distance limitation

Reference Point Height: is the height of the ground station reference point above the WGS-84 ellipsoid.

Reference Station Data Selector (RSDS): is the numerical identifier that is unique on a frequency in the broadcast region and used to select the station for the differential positioning service.

1111 1111 = Positioning service is not provided

Refractivity Index (N_R): is the estimated tropospheric refractivity index at the reference point, coded as a two's complement value with an offset of 400 (i.e., a tropospheric refractivity index of 400 would be coded as all zeros).

Refractivity Uncertainty (σ_N): defines the standard deviation of a normal distribution associated with the residual tropospheric uncertainty such that the uncertainty in the differential troposphere delay correction is:

$$\sigma_{tropo} = \sigma_N h_0 \frac{10^{-6}}{\sqrt{0.002 + \sin^2(\theta)}} \left(1 - e^{-\Delta h / h_0}\right)$$

Scale Height (h_0): is the parameter for scaling the tropospheric refractivity as a function of differential altitude.

$\sigma_{vert\_iono\_gradient}$: is the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation such that the uncertainty in the differential ionosphere delay correction is:

$$\sigma_{iono} = F_{PP} \times \sigma_{vert\_iono\_gradient} \times (x_{air} + 2 \times \tau \times v_{air})$$

where:

F_{PP} = the vertical-to-slant obliquity factor for the given satellite and

$$F_{pp} = \left[1 - \left(\frac{R_e \cos\theta}{R_e + h_I}\right)^2\right]^{-\frac{1}{2}}$$

R_e = radius of the earth = 6378.1363 km

h_I = ionospheric shell height = 350 km

θ = the elevation angle of satellite

$\sigma_{vert\_iono\_gradient}$ = the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation (a parameter provided by the ground subsystem in Message Type 2)

x_{air} = the distance (slant range) in meters between the current aircraft location and the reference point

τ = 100 seconds, the time constant of the smoothing filter

v_{air} = the horizontal speed of the aircraft in meters/sec

2.4.5 Message Type 3 — (Reserved) Ground Based Ranging Source (GBRS) Acquisition Data

Message Type 3 defines information required to use the GBRS. A preliminary message definition is provided in Appendix F.

2.4.6 Message Type 4 — Final Approach Segment (FAS) Construction Data

2.4.6.1 Message Description

The Type 4 message format is defined in Table 2-14. Message Type 4 contains one or more data sets that contain approach data and associated vertical/lateral alert limits. Part of the data set is the FAS data block, which is terminated with a FAS CRC. In addition, each Type 4 message is terminated with a separate message CRC (as defined in the message definition).

Each FAS data block contains the parameters that define a single precision approach. The FAS path is a line in space defined by the Landing Threshold Point/Fictitious Threshold Point (LTP/FTP), Flight Path Alignment Point (FPAP), Threshold Crossing Height (TCH), and the Glide Path Angle (GPA). The local level plane for the approach is a plane perpendicular to the local vertical passing through the LTP/FTP (i.e., tangent to the ellipsoid at the LTP/FTP). Local vertical for the approach is normal to the WGS-84 ellipsoid at the LTP/FTP. The Glide Path Intercept Point (GPIP) is where the final approach path intercepts the local level plane. A typical Final Approach Segment Diagram is shown in Figure 2-8.

The protected FAS data blocks are validated individually by the civil authorities. Contents of a typical FAS data block are depicted in Figure 2-8. The data blocks also include data that allow for an unambiguous FAS selection against the desired approach charts. A Data Set Length field at the beginning of each data set provides the number of bytes in the data set. Other data sets may be defined in the future.

Table 2-14 Format of Message Type 4

Data Content	**Bits Used**	**Range of Values**	**Resolution**
For N Data Sets:			
Data Set Length	8	2 – 212	1
FAS Data Block	304	-	-
FAS Vertical Alert Limit / Approach Status	8	0 – 25.4 m	0.1 m
FAS Lateral Alert Limit / Approach Status	8	0 – 50.8 m	0.2 m

2.4.6.2 Message Type 4 Parameters

Data Set Length: indicates the number of bytes in the data set. A data set includes a FAS data block, FASVAL, FASLAL and the data set length field.

Note: *While the current definition of Type 4 messages has a fixed data set length, it is intended that new FAS data blocks will be defined to support other operations (as identified in the Operation Type field).*

FAS Data Block: contains the construction data for a Final Approach Segment. The content of the data block is defined in Section 2.4.6.3.

FAS Lateral Alert Limit/Approach Status: the value of the broadcast lateral alert limit. A coding of "1111 1111" indicates that the approach is not available.

FAS Vertical Alert Limit/Approach Status: the value of the broadcast vertical alert limit. A coding of "1111 1111" indicates that the vertical guidance is not available.

2.4.6.3 Final Approach Segment (FAS) Data Block

The Final Approach Segment Data Block, defined in Table 2-15, contains the parameters that define a single precision approach. Other FAS Data Blocks may be defined in the future. Figure 2-8 depicts a final approach segment and illustrates the parameters that define the approach path. The data block includes data that allow for an unambiguous FAS selection from the approach chart.

Each FAS data block ends with a FAS CRC to protect the approach design data. The protected FAS data blocks are validated individually by the civil authorities. A separate message CRC protects each complete LAAS message.

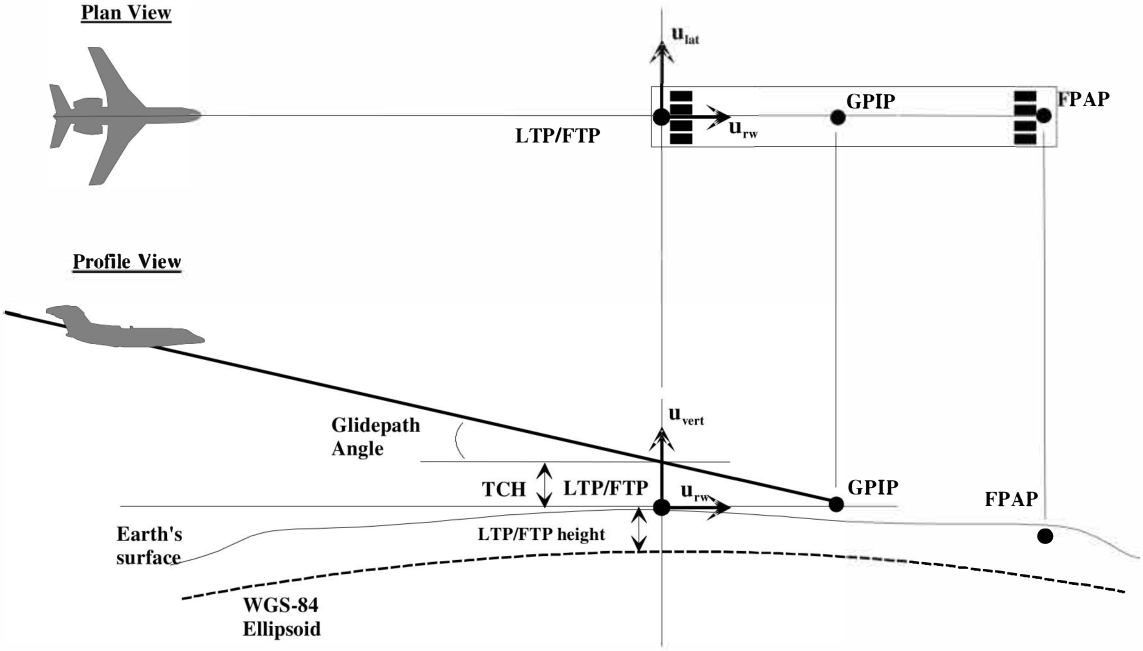

Figure 2-8 Final Approach Segment Diagram

Table 2-15 Final Approach Segment (FAS) Data Block

Data Content	Bits Used	Range of Values	Resolution
Operation Type	4	0 – 15	1
SBAS Service Provider	4	0 – 15	1
Airport ID	32	-	-
Runway Number	6	0 – 36	1
Runway Letter	2	-	-
Approach Performance Designator	3	0 – 7	1
Route Indicator	5	-	-
Reference Path Data Selector	8	0 – 48	1
Reference Path ID	32	-	-
LTP/FTP Latitude	32	± 90.0 °	0.0005 arcsec
LTP/FTP Longitude	32	± 180.0 °	0.0005 arcsec
LTP/FTP Height	16	-512.0 – 6041.5 m	0.1 m
ΔFPAP Latitude	24	± 1 °	0.0005 arcsec
ΔFPAP Longitude	24	± 1 °	0.0005 arcsec
Approach Threshold Crossing Height (TCH)	15	0 – 1638.35 m or 0 – 3276.7 ft	0.05 m or 0.1 ft
Approach TCH Units Selector	1	-	-
Glide Path Angle (GPA)	16	0 – 90.0 °	0.01°
Course Width at Threshold	8	80.0 to 143.75 m	0.25 m
ΔLength Offset	8	0 to 2032 m	8 m
Final Approach Segment CRC	32	-	-

2.4.6.4 Final Approach Segment Parameters

Airport Identification: represents the three or four alphanumeric characters used to designate airport facilities. Each character is coded using bits b_1 to b_6 of its International Alphabet No. 5 representation (reference Section 2.4.2). For each character, bit b_1 is transmitted first, and two zero bits are appended after bit b_6, so that 8 bits are transmitted for each character. The right-most character is transmitted first. Only upper case letters, numbers, and IA-5 "space" ("10 0000") are used. When a three-character identifier is used, the right-most (first transmitted) character is IA-5 "space".

Approach Performance Designator: represents the general information about the approach design. The convention for the coding is as follows:

0	=	Spare
1	=	Category I
2	=	Reserved for Category II
3	=	Reserved for Category III
4 - 7	=	Spare

Approach TCH Units Selector: defines the units used to describe the Approach Threshold Crossing Height. The coding is:

0	=	feet
1	=	meters

Approach Threshold Crossing Height (TCH): the height of the FAS path above the LTP/FTP defined in either feet or meters as indicated by the Approach TCH Units Selector.

CRC code: is a 32 bit cyclic redundancy check (CRC) appended to the end of each FAS Data Block in order to ensure approach data integrity.

The generator polynomial G(x) for the message block CRC is:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

The CRC information field, *M(x), is*

$$M(x) = \sum_{i=1}^{272} m_i x^{272-i} = m_1 x^{271} + m_2 x^{270} + \ldots + m_{272} x^{0}$$

M(x) is formed from all bits of the associated FAS data block, excluding the CRC. Bits are arranged in the order transmitted, such that m_1 corresponds to the LSB of the operation type field, and m_{272} corresponds to the MSB of the ΔLength Offset field.

The CRC is ordered such that r_1 is the first transmitted bit and r_{32} is the last transmitted bit.

Further details of CRC implementation are provided in Appendix A.

Course Width at Threshold: the lateral displacement from the path defined by the FAS at the LTP/FTP at which full-scale course deviation indicator (CDI) deflection is attained. The Course Width field is ignored if Runway Number is coded as 0 (helicopter pad). Instead, the receiver uses a course width of 38 m (125 ft) at the LTP/FTP.

ΔFPAP Latitude: represents the difference of latitude of the runway Flight Path Alignment Point (FPAP) from the LTP/FTP, defined in WGS-84 coordinates and transmitted in arc seconds. Positive values denote the FPAP latitude north of LTP/FTP latitude. Negative values denote the FPAP latitude south of the LTP/FTP latitude.

ΔFPAP Longitude: represents the difference of longitude of the runway Flight Path Alignment Point from the LTP/FTP defined in WGS-84 coordinates and transmitted in arc seconds. Positive values indicate the FPAP longitude east of LTP/FTP longitude. Negative values indicate the FPAP longitude west of LTP/FTP longitude.

ΔLength Offset: distance from the stop end of the runway to the FPAP. A coding of 1111 1111 indicates that the value is not provided.

Glide Path Angle (GPA): represents the angle of the FAS path (glide path) with respect to the horizontal plane tangent to the WGS-84 ellipsoid at the LTP/FTP.

LTP/FTP Height represents the height of the LTP/FTP above the WGS-84 ellipsoid. This is coded as an unsigned value with an offset of –512 meters. A zero value in this field places the LTP/FTP 512 m below the WGS-84 ellipsoid.

LTP/FTP Latitude: represents the latitude of the LTP/FTP in arc seconds. Positive values denote north latitude and negative values denote south latitude.

LTP/FTP Longitude: represents the longitude of the LTP/FTP in arc seconds. Positive values denote east longitude and negative values denote west longitude.

Operation Type: indicates whether the operation is a straight-in approach procedure or other operation to be defined later. The convention for coding is as follows:

0 = straight-in approach procedure

1-15 = spare

Note 1: *Other operations could include straight-in approaches followed by a missed-approach, precision curved approach or departure procedures, and rollout and taxiing procedures.*

Reference Path Data Selector: is a numerical identifier (unique in the broadcast region) used to select the FAS data block (desired approach).

Note 2: *The Reference Path Data Selector is the only identifier guaranteed to be unique to one FAS data block among all of the FAS data blocks within the radio range of the ground reference station on the tuned frequency.*

Reference Path Identifier: represents the three or four alphanumeric characters used to designate the reference path. Alphanumeric characters are coded using bits b_1 to b_6 of International Alphabet No. 5 (reference Section 2.4.2). For each character, bit b_1 is transmitted first, and two zero bits are appended after bit b_6, so that 8 bits are transmitted for each character. The right-most character is transmitted first. Only upper case alpha characters, numbers, and IA-5 "space" ("10 0000") are used. When a three-character identifier is used, the right-most (first transmitted) character is IA-5 "space".

Route Indicator: is a single alphabetic character used to differentiate between multiple approaches to the same runway end, coded using bits b_1 to b_5 of International Alphabet No. 5 (reference Section 2.4.2). Only upper case letters (excluding "I" and "O"), or IA-5 "space" may be used.

Runway Letter: represents the runway letter, where used to differentiate between parallel runways. The convention for coding is as follows:

0 = no letter	2 = C (center)
1 = R (right)	3 = L (left)

Runway Number: represents the approach runway number. The designation 0 identifies heliport operations.

SBAS Service Provider: this field is used by SBAS equipment to associate the data with an SBAS service provider. This field has no application for the LAAS user and should be ignored (except for the CRC and FEC calculations) in this LAAS application.

2.4.7 Message Type 5 — Ranging Source Availability (optional)

2.4.7.1 Message Description

Message Type 5 provides a means for the ground subsystem to indicate to the aircraft avionics the future availability of differential corrections to the ranging measurements on an approach specific basis.

Message Type 5 consists of rising and setting information for the currently visible or soon to be visible ranging sources as shown in Table 2-16. This message allows the ground subsystem to broadcast predicted changes in the availability of differential corrections at future specific points in time to the aircraft so that the aircraft is able to anticipate the ranging sources that can be used for the duration of a specific precision approach.

This message is designed to allow for unique approaches where ranging sources are masked differently than the LGF.

Table 2-16 Format of Message Type 5

Data Content	Bits Used	Range of Values	Resolution
Modified Z-count	14	0 - 1199.9 sec	0.1 sec
Spare	2	-	-
Number of Impacted Sources (N)	8	0 – 31	1
For N Impacted Ranging Sources:			
Ranging Source ID	8	1 – 255	1
Source Availability Sense	1	-	-
Time to Source Availability Change (Note 1)	7	0 – 1270 sec	10 sec
Number of Obstructed Approaches (A)	8	0 – 255	1
For A Obstructed Approaches:			
Reference Path Data Selector (RPDS)	8	0 – 48	1
Number of Impacted Sources for this Approach (N_A)	8	1 – 31	1
For N_A Impacted Sources for this Approach:			
Ranging Source ID	8	1 – 255	1
Source Availability Sense	1	-	-
Source Availability Duration (Note 1)	7	0 – 1270 sec	10 sec

Note: *111 1111 indicates 1270 seconds or longer.*

2.4.7.2 Message Type 5 Parameters

Modified Z-count: is defined as in Message Type 1.

Number of Impacted Sources: indicates the number of ranging sources for which duration information applicable to all approaches is provided.

Number of Obstructed Approaches: indicates the number of approaches (A) for which duration information applicable to only a specific approach is provided. The "Number of

Obstructed Approaches" field is followed by (A) repetitions of source information. Each repetition includes: the number of impacted sources (N_A), followed by (N_A) repetitions of a source ID, the source availability sense, and the source availability duration (see Table 2-16). The value "0" indicates that there are no unique obstructions on any approach.

Ranging Source ID: is defined as in Message Type 1.

Reference Path Data Selector: Indicates the FAS data block to which the source availability data applies.

Source Availability Sense: indicates whether the ranging source or its differential corrections will become available or cease to be available. A coding of "0" indicates that a ranging source or its corrections will soon cease to be available, and "1" indicates that a ranging source and its corrections will soon be available.

Source Availability Duration: is the period of time for which a ranging source or its corrections are expected to remain available, or within which the ranging source and its corrections are expected to become available (depending upon coding of Source Availability Sense). The time is relative to the modified z-count coded in the message. A coding of "111 1111" indicates a time period greater than or equal to 1270 seconds.

Number of Impacted Sources for this Approach (N_A): is the number of sources for which duration information applicable only to this approach is provided.

2.4.8 Message Type 6 — (Reserved) Differential Carrier Corrections

Message Type 6 is reserved for future carrier correction definition. A preliminary definition is provided in Appendix C.

2.4.9 Message Type 7 — (Reserved) for Military

Message Type 7 is reserved for military applications.

2.4.10 Message Type 8 — (Reserved) for Test

Message Type 8 is reserved for test.

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Appendix A

CYCLIC REDUNDANCY CHECKS (CRCs)

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Appendix A—CYCLIC REDUNDANCY CHECKS (CRCs)

A.1 CRC Definition

Cyclic Redundancy Check fields are appended to critical data components to increase the level of assurance that the data are correct and increase system integrity.

Each CRC is calculated as the remainder R(x) of the modulo-2 division of two binary polynomials:

$$\left\{\frac{\left[x^k M(x)\right]}{G(x)}\right\}_{\text{mod } 2} = Q(x) + \frac{R(x)}{G(x)}$$

where:

k is the number of bits in the particular CRC.

M(x) is the information field, which consists of the sequence of data items to be protected by the particular CRC, represented as a polynomial.

G(x) is the generator polynomial specified for the particular CRC.

Q(x) is the quotient of the division.

R(x), the remainder of the division, contains the CRC:

$$R(x) = \sum_{i=1}^{k} r_i x^{k-i} = r_1 x^{k-1} + r_2 x^{k-2} + \ldots + r_k x^0$$

Note 1: *The M(x) and G(x) polynomials are defined in Section 2.4.3.2 for the ephemeris CRC, Section 2.3.7 for the message block CRC, and Section 2.4.6.4 for the FAS CRC.*

Note 2: *Coefficient r_1 is the first bit of the CRC to be transmitted.*

Figure A-1 shows an example polynomial division circuit to generate the 16-bit Ephemeris CRC field in the Type 1 message. The register is seeded with all zeros. After all bits of M(x) are clocked into the register, the CRC is in the register with coefficient r_1 in position x^{15}.

Figure A-2 shows an example polynomial division circuit to generate the 32-bit LAAS message CRC. The same implementation could be used to generate the FAS CRC. The register is initially seeded with all zeros. After all bits of M(x) are clocked into the register, the CRC is in the register with coefficient r_1 in position x^{31}.

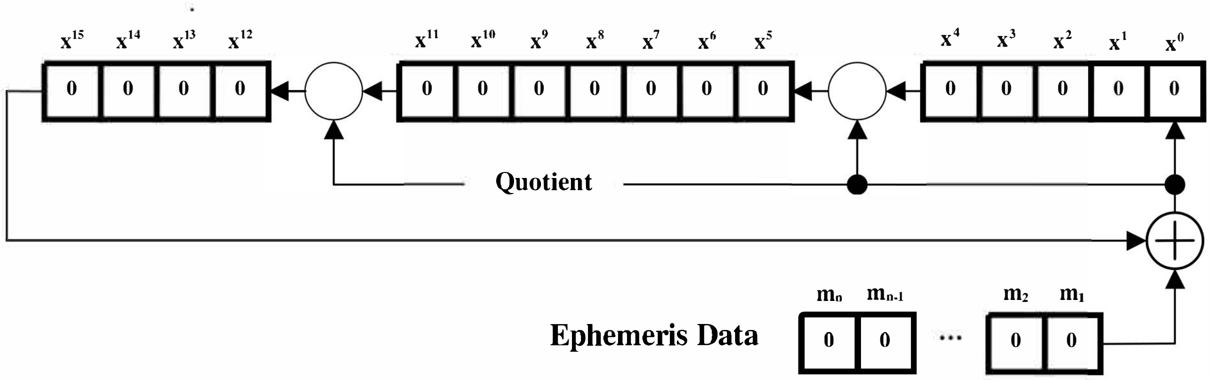

Figure A-1 Example of Ephemeris CRC Generator Circuit

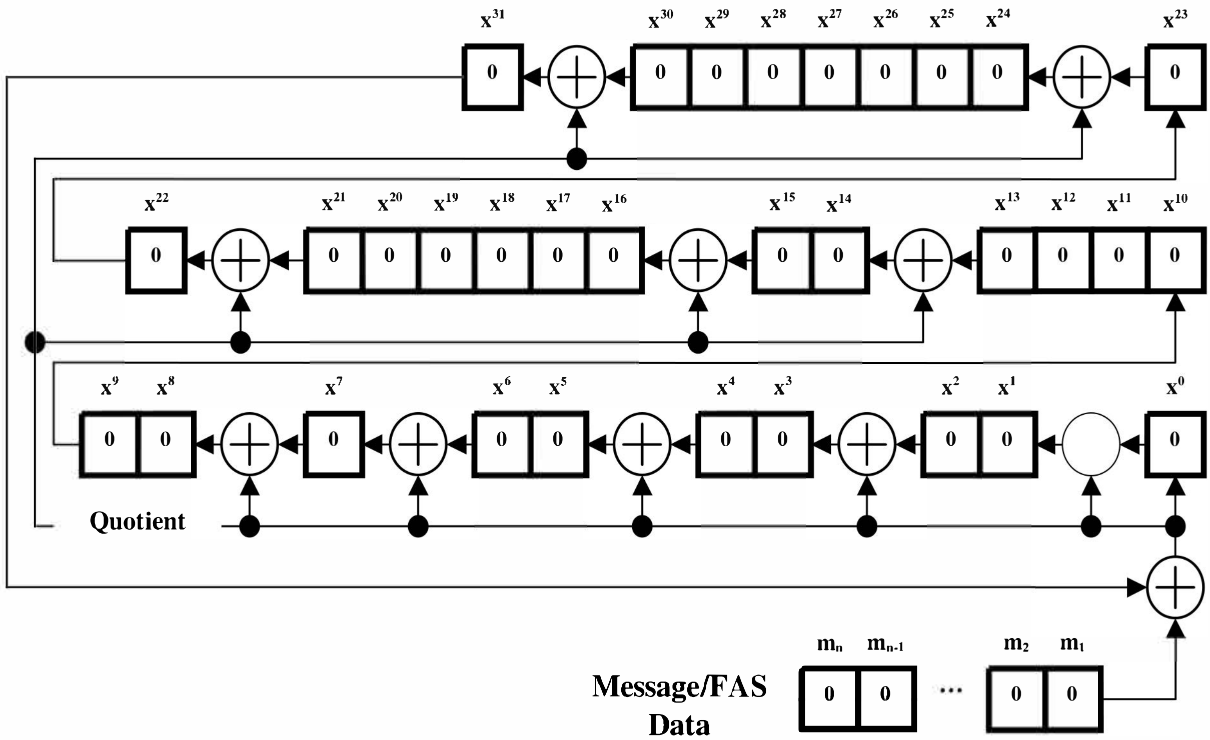

Figure A-2 Example of LAAS Message or FAS Data Block CRC Generator Circuit

Table A-1 provides examples of 16-bit ephemeris CRC values calculated using various artificial bit patterns for the ephemeris data. Table A-2 provides examples of 32-bit LAAS message or FAS data block CRC values calculated using various artificial bit patterns and lengths for M(x).

Table A-1 Examples of 16-bit Ephemeris CRC

Length of M(x)	**Ephemeris Data** (Note 3)	**CRC** (Note 4)
n = 576 bits	1111… 1111	0110 0001 0110 1110
n = 576 bits	1010 … 1010	1011 1001 1011 1011
n = 576 bits	0101 … 0101	1101 1000 1101 0101

Note 3: *The ephemeris data is shown with Subframe 1, bit 61* at *left, Subframe 3, bit 294 at right. This data must be ANDed with ephemeris mask and reordered by reversing bits within each byte to form M(x) for CRC calculation.*

Note 4: *The CRC values are shown with r_1 at right.*

Table A-2 Examples of 32-bit LAAS Message or FAS Data Block CRC

Length of M(x)	**M(x) Bit Pattern** (Note 5)	**CRC** (Note 5)
n = 272 bits	1111… 1111	0001 1100 0100 0110 1010 1011 1110 0011
n = 480 bits	1111… 1111	0010 1101 0110 0101 0100 1111 0111 1010
n = 272 bits	1010 … 1010	1000 1110 1000 0111 1100 1110 0100 0011
n = 480 bits	1010 … 1010	0011 0110 0100 0110 0111 0101 1010 1100
n = 272 bits	0101 … 0101	1001 0010 1100 0001 0110 0101 1010 0000
n = 480 bits	0101 … 0101	0001 1011 0010 0011 0011 1010 1101 0110

Note 5: *M(x) values are shown with m_1 at right. CRC values are shown with r_1 at lower right.*

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Appendix B

MESSAGE AND FAS EXAMPLES

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Appendix B—MESSAGE AND FAS EXAMPLES

B.1 Message and FAS Example

This appendix provides examples of the coding of LAAS Type 1, 2, 4 and 5 messages. The examples illustrate the coding of the various application parameters, including the CRC and FEC parameters, and the results of bit scrambling and D8PSK symbol coding.

Note 1: *The engineering values for the message parameters have been selected to illustrate the message coding process. They are not necessarily representative of realistic values.*

Table B-1 provides an example of a Type 1 message. For illustration purposes, the Additional Message Flag field is coded to indicate that this is the first of two Type 1 messages to be broadcast within the same frame. (Table B-2 provides the companion message.)

Table B-2 provides examples of a Type 1 message and a Type 2 message coded within a single burst (i.e., two messages to be broadcast within a single transmission slot). The Additional Message Flag field of the Type 1 message is coded to indicate that it is the second of two Type 1 messages to be broadcast within the same frame. The Type 2 message includes Additional Data Block 1.

Note 2: *A second Type 1 message is not typically required, except to broadcast more ranging source corrections than a single message can accommodate.*

Table B-3 provides an example of a Type 4 message containing two FAS data blocks.

Table B-4 provides an example of a Type 5 message. In this example, source availability durations common to all approaches are provided for two satellites. Additionally, source availability durations for two individual approaches are provided: two satellites for one approach, one satellite for another approach.

Table B-1 Example of Type 1 Message

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 3)
Power Stabilization	15	-	-	-	000 0000 0000 0000
Synchronization and Ambiguity Resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
Station Slot Identifier	3	-	-	E	100
Transmission Length	17	0 – 1824 bits	1 bit	536 bits	0 0000 0010 0001 1000
Training Sequence FEC	5	-	-	-	00001
Message Block Header					
Message Block Identifier	8	-	-	"Normal"	1010 1010
GBAS ID	24			BELL	000010 000101 001100 001100
Message Type Identifier	8	–1-8	1	1	0000 0001
Message Length	8	10 – 222 bytes	1 byte	61 bytes	0011 1101
Message					
Modified Z-count	14	0 – 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional Message Flag	2	0 – 3	-	1^{st} of pair	01
Number of Measurements	5	0 - 18	1	4	00100
Measurement Type	3	0 – 7	-	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 – 1.275×10^{-3} m/m	5×10^{-6} m/m	1×10^{-4}	0001 0100
Ephemeris CRC	16	-	-	-	0000 0000 0000 0000 (Note 4)
Source Availability Duration	8	0 - 2540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging Source ID	8	1 - 255	1	2	0000 0010
Issue of Data (IOD)	8	0 - 255	1	255	1111 1111
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 - 5.08 m	0.02 m	0.98 m	0011 0001
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B_3	8	±6.35 m	0.05 m	-0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Measurement Block 2					
Ranging Source ID	8	1 - 255	1	4	0000 0100
Issue of Data (IOD)	8	0 - 255	1	126	0111 1110
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m	-1.0 m	1111 1111 1001 1100
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s	+0.2 m/s	0000 0000 1100 1000
σ_{pr_gnd}	8	0 - 5.08 m	0.02 m	0.34 m	0001 0001
B_1	8	±6.35 m	0.05 m	+0.20 m	0000 0100
B_2	8	±6.35 m	0.05 m	+0.30 m	0000 0110

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 3)
B_3	8	±6.35 m	0.05 m	-0.50 m	1111 0110
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Measurement Block 3					
Ranging Source ID	8	1 - 255	1	12	0000 1100
Issue of Data (IOD)	8	0 - 255	1	222	1101 1110
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m	+1.11 m	0000 0000 0110 1111
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 - 5.08 m	0.02 m	1.02 m	0011 0011
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.25 m	0000 0101
B_3	8	±6.35 m	0.05 m	-0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Measurement Block 4					
Ranging Source ID	8	1 - 255	1	23	0001 0111
Issue of Data (IOD)	8	0 - 255	1	80	0101 0000
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m	-2.41 m	1111 1111 0000 1111
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.96 m/s	1111 1100 0100 0000
σ_{pr_gnd}	8	0 - 5.08 m	0.02 m	0.16 m	0000 1000
B_1	8	±6.35 m	0.05 m	+0.20 m	0000 0100
B_2	8	±6.35 m	0.05 m	+0.30 m	0000 0110
B_3	8	±6.35 m	0.05 m	-0.50 m	1111 0110
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block CRC	32	-	-	-	1100 0010 1111 0011 0000 1011 1100 1010
Application FEC	48				0110 0011 1110 1001 1110 0000 1110 1101 0010 1001 0111 0101
Input to Bit Scrambling (Note 5)	0 46 10 10 55 30 CA 10 80 BC 17 C2 20 28 00 00 FF 40 FF 26 00 1C FF 8C 40 C0 DF 01 20 7E 39 FF 13 00 88 20 60 6F 01 30 7B F6 00 1C FF CC 40 A0 DF 01 E8 0A F0 FF 02 3F 10 20 60 6F 01 53 D0 CF 43 AE 94 B7 07 97 C6				
Output from Bit Scrambling	0 60 27 98 1F 2F D2 3B 5F 26 C2 1B 12 F4 46 D0 09 81 B6 25 1C 18 D0 7C 2A 7F B9 55 A8 B0 27 17 3A 60 EB 5F 1B 3B A5 FE 0A E1 43 D7 FA D7 B3 7A 65 D8 4E D7 79 D2 E1 AD 95 E6 6D 67 12 B3 EA 4F 1A 51 B6 1C 81 F2 31				
Fill Bits	-	-	-	-	
D8PSK Symbols (Note 6)	0000 0035 1120 4546 3165 0100 1270 7716 7164 5524 7403 5772 2623 4621 4531 1123 2246 0075 5223 2477 1661 7052 0475 0422 0772 4363 4073 3535 0512 0746 4574 1125 2254 5252 7317 1513 5104 7466 1317 1745 1062 2642 1715 7064 6734 5046 3654 1025 0713 5576 5574 5512 222				

Note 3: *In the Binary Representation column, the rightmost bit is the LSB of the binary parameter value, and is the first bit transmitted or sent to the bit scrambling process. All data fields are sent in the order specified in the table.*

Note 4: *For examples of Ephemeris CRC calculation, see Appendix A, Table A-1.*

Note 5: *This string is coded in hexadecimal with the first bit to be sent to the bit scrambling process as its MSB. The first character represents a single bit.*

Note 6: *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of $\pi/4$ radians (e.g., a value of 5 represents a phase of $5\pi/4$ radians relative to the first symbol).*

Table B-2 Example of Type 1 and Type 2 Messages in One Burst

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 7)
Power Stabilization	15	-	-	-	000 0000 0000 0000
Synchronization and Ambiguity Resolution	48	-	-	-	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
Station Slot Identifier	3	-	-	E	100
Transmission Length	17	0 – 1824 bits	1 bit	544 bits	0 0000 0010 0010 0000
Training Sequence FEC	5	-	-	-	00000
First Message Block (Type 1 Message)					
Message Block Header					
Message Block Identifier	8	-	-	"Normal"	1010 1010
GBAS ID	24			BELL	000010 000101 001100 001100
Message Type Identifier	8	1 - 8	1	1	0000 0001
Message Length	8	10 – 222 bytes	1 byte	28 bytes	0001 1100
Message					
Modified Z-count	14	0 – 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional Message Flag	2	0 3	-	2nd of pair	11
Number of Measurements	5	0 – 18	1	1	00001
Measurement Type	3	0 - 7	-	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 – 1.275×10^{-3} m/m	5×10^{-6} m/m	0(SBAS)	0000 0000
Ephemeris CRC	16	-	-	-	0000 0000 0000 0000 (Note 8)
Source Availability Duration	8	0 - 2540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging Source ID	8	1 - 255	1	122	0111 1010
Issue of Data (IOD)	8	0 - 255	1	2	0000 0010
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 - 5.08 m	0.02 m	1.96 m	0110 0010
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B_3	8	±6.35 m	0.05 m	-0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block CRC	32	-	-	-	1011 0101 1101 0000 1011 1100 0101 0010

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 7)
Second Message Block (Type 2 Message)					
Message Block Header					
Message Block Identifier	8			Normal	1010 1010
GBAS ID	24	-	-	BELL	000010 000101 001100 001100
Message Type Identifier	8	1 - 8	1	2	0000 0010
Message Length	8	10 – 222 bytes	1 byte	34 bytes	0010 0010
Message					
Ground Station Installed Receivers	2	2 - 4	1	3	01
Ground Station Accuracy Designator	2	-	-	B	01
Spare	1	-	-	-	0
Ground Station Continuity/ Integrity Designator	3	0 – 7	1	1	001
Local Magnetic Variation	11	± 180°	0.25°	E58.0°	000 1110 1000
Spare	5	-	-	-	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 - 25.5 mm/km	0.1 mm/km	0	0000 0000
Refractivity Index	8	16 to 781	3	379	1111 1001
Scale Height	8	0 - 25,500 m	100 m	100 m	0000 0001
Refractivity Uncertainty	8	0 – 255	1	20	0001 0100
Latitude	32	± 90.0°	0.0005 arcsec	N45° 40' 32" (+164432")	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	± 180.0°	0.0005 arcsec	W93° 25' 13" (-336313")	1101 0111 1110 1000 1000 1010 1011 0000
Reference Point Height	24	± 83,886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference Station Data Selector	8	0 – 48	1	5	0000 0101
Maximum Use Distance (D_{max})	8	2 – 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 – 12.75	0.05	6	0111 1000
$K_{md\_e\_CAT1,GPS}$	8	0 – 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 – 12.75	0.05	0	0000 0000
$K_{md\_e\_CAT1,GLONASS}$	8	0 – 12.75	0.05	0	0000 0000
Message Block CRC	32	-	-	-	0101 1101 0111 0110 0010 0011 0001 1110
Application FEC	48	-	-	-	1110 1000 0100 0101 0011 1011 0011 1011 0100 0001 0101 0010

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 7)
Input to Bit Scrambling (Note 9)	0 41 10 00 55 30 CA 10 80 38 17 C3 80 00 00 00 FF 5E 40 26 00 1C FF 46 40 C0 DF 01 4A 3D 0B AD 55 30 CA 10 40 44 A4 17 00 00 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 78 C4 6E BA 4A 82 DC DC A2 17				
Output from Bit Scrambling	0 67 27 88 1F 2F D2 3B 5F A2 C2 1A B2 DC 46 D0 09 9F 09 25 1C 18 D0 B6 2A 7F B9 55 C2 F3 15 45 7C 50 A9 6F 3B 10 00 D9 71 17 DC 4B 2D 1B 7B 83 72 D4 F7 CA 62 C8 D9 12 25 5E 13 2E 13 E0 42 44 37 45 68 29 5A B9 55 65				
Fill Bits	-	-	-	-	0
D8PSK Symbols (Note 10)	0000 0035 1120 4546 3165 0105 6744 3352 3520 1160 3050 1336 6202 3576 1206 6670 7400 7653 3001 0255 3103 1274 2617 2772 7623 6442 4117 7201 3513 1033 3342 1734 4275 1235 6034 2057 6627 0254 1743 1214 0342 1036 7031 6613 4656 7433 6654 7730 3473 2201 4060 7506 0144 44				

Note 7: *In Binary Representation column, the rightmost bit is the LSB of the binary parameter value, and is the first bit transmitted or sent to the bit scrambling process. All data fields are sent in the order specified in the table.*

Note 8: *For examples of Ephemeris CRC calculation, see Appendix A, Table A-1.*

Note 9: *This string is coded in hexadecimal with the first bit to be sent to the bit scrambling process as its MSB. The first character represents a single bit.*

Note 10: *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of π/4 radians (e.g., a value of 5 represents a phase of 5π/4 radians relative to the first symbol). Fill bits are 0.*

Note 11: *In the example, the fill bits are not scrambled.*

Table B-3 Example of Type 4 Message

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 12)
Power Stabilization	15	-	-	-	000 0000 0000 0000
Synchronization and Ambiguity Resolution	48	-	-	-	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
Station Slot Identifier	3	-	-	D	011
Transmission Length	17	0 – 1824 bits	1 bit	784 bits	0 0000 0011 0001 0000
Training Sequence FEC	5	-	-	-	00000
Message Block Header					
Message Block Identifier	8	-	-	"Normal"	1010 1010
GBAS ID	24	-	-	CMJ	0000 1100 1101 0010 1010 0000
Message Type Identifier	8	1 - 8	1	4	0000 0100
Message Length	8	10 - 222 bytes	1 byte	92 bytes	0101 1100
Message					
Data Set 1					
Data Set Length	8	2 – 212 bytes	1 byte	41 bytes	0010 1001
Operation Type	4	0 – 15	1	0	0000
Operation Type	4	0 – 15	1	0	0000
SBAS Service Provider	4	0 - 15	1	15	1111
Airport ID	32	-	-	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway Number	6	0 – 36	1	15	00 1111
Runway Letter	2	-	-	R	01
Approach Performance Designator	3	0 – 7	1	Cat I	001
Route Indicator	5	-	-	C	00001
Reference Path Data Selector	8	0 – 48	1	3	0000 0011
Reference Path ID	32	-	-	GTBS	0000 0111 0001 0100 0000 0010 0001 0011
LTP/FTP Latitude	32	± 90.0°	0.0005 arcsec	43.6441075°N	0001 0010 1011 1010 1110 0010 1000 0110
LTP/FTP Longitude	32	± 180.0°	0.0005 arcsec	1.345940°W	0000 0000 1001 0011 1101 1110 1001 0000
LTP/FTP Height	16	-512.0 – 6041.5 m	0.1 m	197.3 m	0001 1011 1101 0010
ΔFPAP Latitude	24	± 1°	0.0005 arcsec	-0.025145°	1111 1101 0011 1100 1100 1100
ΔFPAP Longitude	24	± 1°	0.0005 arcsec	0.026175°	0000 0010 1110 0000 0010 1100
Approach Threshold Crossing Height (TCH)	15	0- 3276.7 ft 0 – 1638.35 m	0.1 ft 0.05 m	17.05 m.	000 0001 0101 0101
Approach TCH Units Selector	1	-	-	meters	1
Glidepath Angle (GPA)	16	0 - 90.0 °	0.01°	3°	0000 0001 0010 1100
Course Width	8	80.0 - 143.75 m	0.25 m	105	0110 0100
ΔLength Offset	8	0 – 2032 m	8 m	0 m	0000 0000

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 12)
Final Approach Segment CRC	32	-	-	-	1010 0010 1010 0101 1010 1000 0100 1101
FAS Vertical Alert Limit / Approach status	8	0 – 25.4 m	0.1 m	10 m	0110 0100
FAS Lateral Alert Limit / Approach status	8	0 – 50.8 m	0.2 m	40 m	1100 1000
Data Set 2					
Data Set Length	8	2 – 212 bytes	1 byte	41 bytes	0010 1001
Operation Type	4	0 – 15	1	0	0000
SBAS Service Provider	4	0 – 15	1	1	0001
Airport ID	32	-	-	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway Number	6	0 – 36	1	33	10 0001
Runway Letter	2	-	-	R	01
Approach Performance Designator	3	0 – 7	1	Cat I	001
Route Indicator	5	-	-	A	00001
Reference Path Data Selector	8	0 – 48	1	21	0001 0101
Reference Path ID	32	-	-	GTN	0000 0111 0001 0100 0000 1110 0010 0000
LTP/FTP Latitude	32	± 90.0 °	0.0005 arcsec	43.6156350°N	0001 0010 1011 0111 1100 0001 1011 1100
LTP/FTP Longitude	32	± 180.0 °	0.0005 arcsec	1.3802350°E	0000 0000 1001 0111 1010 0011 0001 1100
LTP/FTP Height	16	-512.0 – 6041.5 m	0.1 m	200.2 m	0001 1011 1101 0010
ΔFPAP Latitude	24	± 1 °	0.0005 arcsec	0.02172375°	0000 0010 0110 0010 1111 1011
ΔFPAP Longitude	24	± 1 °	0.0005 arcsec	-0.0226050°	1111 1101 1000 0100 0011 1100
Approach Threshold Crossing Height (TCH)	15	0- 3276.7 ft 0 – 1638.35 m	0.1 ft 0.05 m	15.25 m.	000 0001 0011 0001
Approach TCH Units Selector	1	-	-	meters	1
Glidepath Angle (GPA)	16	0 - 90.0 °	0.01°	3.01°	0000 0001 0010 1101
Course Width	8	80.0 - 143.75 m	0.25 m	105	0110 0100
ΔLength Offset	8	0 – 2032 m	8 m	0 m	0000 0000
Final Approach Segment CRC	32				1010 1111 0100 1101 1010 0000 1101 0111
FAS Vertical Alert Limit / Approach status	8	0 – 25.4 m	0.1 m	10 m	0110 0100
FAS Lateral Alert Limit / Approach status	8	0 – 50.8 m	0.2 m	40 m	1100 1000
Message Block CRC	32	-	-	-	0101 0111 0000 0011 1111 1110 1001 1011
Application FEC	48	-	-	-	0001 1011 1001 0001 0010 1010 1011 1100 0010 0101 1000 0101

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 12)
Input to Bit Scrambling (Note 13)	1 82 30 00 55 05 4B 30 20 3A 94 0F F0 40 60 30 F2 98 C0 C8 40 28 E0 61 47 5D 48 09 7B C9 00 AD D8 33 3C BF 34 07 40 AA 81 34 80 26 00 B2 15 A5 45 26 13 94 08 F0 40 60 30 86 90 A8 04 70 28 E0 3D 83 ED 48 38 C5 E9 00 4B D8 DF 46 40 3C 21 BF 8C 81 B4 80 26 00 EB 05 B2 F5 26 13 D9 7F C0 EA A1 A4 3D 54 89 D8				
Output from Bit Scrambling	1 A4 07 88 1F 1A 53 1B FF A0 41 D6 C2 9C 26 E0 04 59 89 CB 5C 2C CF 91 2D E2 2E 5D F3 07 1E 45 F1 53 5F C0 4F 53 E4 64 F0 23 C3 ED 05 A9 E6 7F FF FF B5 49 81 DD A3 F2 B5 40 9D A0 17 90 12 60 64 7C CF E3 BE A0 1E 72 FF 61 6E E4 02 44 D9 1E D2 FD 63 D1 12 C3 5A 00 0E F8 89 FE 4C 12 0C 78 4F 9D 55 08 16 F6				
Fill Bits	0-2	-	-	-	0
D8PSK Symbols (Note 14)	0000 0035 1120 4546 3165 0432 2300 7716 6217 0713 0525 5667 3176 7243 4537 7776 1577 6346 1661 5705 4361 5214 5764 0513 3401 6775 2142 3130 4443 0613 0115 0266 7743 4175 5603 2762 4163 0527 5365 4001 5247 0514 2032 2575 3334 6255 5437 7076 0565 2760 6314 4462 4316 3101 3537 2225 0120 7604 0752 6435 1034 5771 4077 7704 1566 5273 6001 2232 4007 4020 3144 3362 7544 44				

Note 12: *In the Binary Representation column, the rightmost bit is the LSB of the binary parameter value, and is the first bit transmitted or sent to the bit scrambling process. All data fields are sent in the order specified in the table.*

Note 13: *This string is coded in hexadecimal with the first bit to be sent to the bit scrambling process as its MSB. The first character represents a single bit.*

Note 14: *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of $\pi/4$ radians (e.g., a value of 5 represents a phase of $5\pi/4$ radians relative to the first symbol).*

Note 15: *In the example, the fill bits are not scrambled.*

Table B-4 Example of Type 5 Message

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 16)
Power Stabilization	15	-	-	-	000 0000 0000 0000
Synchronization and Ambiguity Resolution	48	-	-	-	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
Station Slot Identifier	3	-	-	D	011
Transmission Length	17	0 – 1824 bits	1 bit	272 bits	0 0000 0001 0001 0000
Training Sequence FEC	5	-	-	-	00011
Message Block Header					
Message Block Identifier	8	-	-	"Normal"	1010 1010
GBAS ID	24	-	-	CMJ	000011 001101 001010 100000
Message Type Identifier	8	1 - 8	1	5	0000 0101
Message Length	8	10 – 222 bytes	1 byte	28 bytes	0001 1100
Message					
Modified Z-count	14	0 – 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Spare	2	-	-	-	00
Number of Impacted Sources	8	0 - 31	1	2	0000 0010
First impacted source					
Ranging Source ID	8	1 - 255	1	4	0000 0100
Source Availability Sense	1	-	-	will cease	0
Source Availability Duration	7	0 - 1270 s	10 s	50 s	000 0101
Second impacted source					
Ranging Source ID	8	1 - 255	1	3	0000 0011
Source Availability Sense	1	-	-	will start	1
Source Availability Duration	7	0 - 1270 s	10 s	200 s	001 0100
Number of Obstructed Approaches	8	0 - 255	1	2	0000 0010
First obstructed approach					
Reference Path data Selector	8	0 – 48	1	21	0001 0101
Number of Impacted Sources for first obstructed approach	8	0 - 31	1	2	0000 0010
First impacted ranging source of first obstructed approach					
Ranging Source ID	8	1 – 255	1	12	0000 1100
Source Availability Sense	1	-	-	will cease	0
Source Availability Duration	7	0 – 1270 s	10 s	250 s	001 1001
Second impacted ranging source of first obstructed approach					
Ranging Source ID	8	1 – 255	1	14	0000 1110
Source Availability Sense	1	-	-	will cease	0
Source Availability Duration	7	0 – 1270 s	10 s	1000 s	110 0100
Second obstructed approach					
Reference Path data Selector	8	0 – 48	1	14	0000 1110
Number of Impacted Sources for second obstructed approach	8	0 - 31	1	1	0000 0001

Data Content	Bits Used	Range of Values	Resolution	Value	Binary Representation (Note 16)
First impacted ranging source of second obstructed approach					
Ranging Source ID	8	1 – 255	1	12	0000 1100
Source Availability Sense	1			will cease	0
Source Availability Duration	7	0 – 1270 s	10 s	220 s	001 0110
Message Block CRC	32	-	-	-	1101 1011 0010 1111 0001 0010 0000 1001
Application FEC	48	-	-	-	0011 1110 1011 1010 0001 1110 0101 0110 1100 1011 0101 1011.
Input to Bit Scrambling (Note 17)	1 82 20 18 55 05 4B 30 A0 38 17 C0 40 20 50 C0 94 40 A8 40 30 4C 70 13 70 80 30 34 90 48 F4 DB DA D3 6A 78 5D 7C				
Output from Bit Scrambling	1 A4 17 90 1F 1A 53 1B 7F A2 C2 19 72 FC 16 10 62 81 E1 43 2C 48 5F E3 1A 3F 56 60 18 86 EA 33 F3 B3 09 07 26 28				
Fill Bits	0-2	-	-	-	
D8PSK Symbols (Note 18)	0000 0035 1120 4546 3165 0432 2056 6605 5106 7602 4161 2447 7363 4632 2070 0103 2240 0660 1332 1241 6623 1163 6437 7711 0173 1157 4302 3234 4514 6644 444				

Note 16: *In the Binary Representation column, the rightmost bit is the LSB of the binary parameter value, and is the first bit transmitted or sent to the bit scrambling process. All data fields are sent in the order specified in the table.*

Note 17: *This string is coded in hexadecimal with the first bit to be sent to the bit scrambling process as its MSB. The first character represents a single bit.*

Note 18: *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of π/4 radians (e.g., a value of 5 represents a phase of 5π/4 radians relative to the first symbol).*

Appendix C

PRELIMINARY CARRIER CORRECTIONS MESSAGE DEFINITION (INFORMATIVE)

Note: *This appendix remains unchanged from DO-246. Maturation of a carrier correction message may occur in the future.*

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Appendix C—PRELIMINARY CARRIER CORRECTIONS MESSAGE DEFINITION (INFORMATIVE)

C.1 Carrier Correction

The Carrier Correction may be used to increase the accuracy of the LAAS system in the future. Message Type 6 is reserved to provide differential carrier correction data for individual GNSS ranging sources. It consists of the corrections for a variable number of ranging sources, as described in Table C-1. The definition in this appendix is included to provide an allocation for the required broadcast data capacity when using carrier corrections.

C.1.1 Definition of Parameters

B1 to B4: are the estimates of the error resulting from specific reference receiver measurements on the carrier corrections and are defined as the differences between the broadcast carrier corrections and the corrections obtained excluding the specific reference receiver measurement. These parameters are two's complement numbers. The bit pattern "1000 0000" indicates that the carrier measurement from the associated LAAS receiver is invalid.

Carrier Correction: is the carrier correction for the ranging source referenced.

Carrier Correction Rate: is the carrier correction rate computed by the LAAS ground reference station and transmitted through the VHF Data Broadcast.

Issue of Data: is ranging source IOD stamp at the time of the corrections and is included for comparison to the received ranging source IOD value in the airborne subsystem.

Measurement Type: identifies the type of ranging signal the measurement is based:

0 = C/A code L1

1 = C/A code L2

2 = P(Y) code L1

3 = P(Y) code L2

4 – 7 = Reserved

Modified Z-count: indicates the reference time for all message parameters in this message (including carrier correction and carrier correction rate). The modified z-count correlates with GPS time, except that it resets on the hour (xx:00), twenty minutes past the hour (xx:20), and forty minutes past the hour (xx:40). The reference time is defined to be the time at which the carrier corrections for all ranging sources are valid.

Number of Measurements: identifies the number of ranging source measurements in the message.

Ranging Source ID: identifies the ranging source to which subsequent corrections are applicable.

1 to 37	=	a GPS satellite whose PRN is equal to the Ranging Source ID value.
38 to 61	=	a GLONASS satellite whose slot is equal to the Ranging Source ID value plus 37.
62 to 119	=	reserved.
120 to 138	=	an SBAS satellite whose PRN is equal to the Ranging Source ID value.
139 to 255	=	reserved.

σ_{pr_gnd}: is the standard deviation of a normal distribution that bounds the SIS contribution to the error in the corrected carrier. The normal distribution $N(0, \sigma^2_{pr\_gnd})$ bounds the error under the H_0 hypothesis. In addition, the normal distribution $N(B_j, M\sigma^2_{pr\_gnd}/(M-1))$ bounds the error under the H_1 hypotheses for a fault in the j^{th} receiver measurement. A coding of "1111 1111" indicates that carrier corrections for a ranging source have been identified as invalid by the ground system.

C.2 Message Table — Carrier Corrections

Table C-1 Format of Message Type 6

Data Content	Bits Used	Range of Values	Resolution
Modified Z-count	14	0 – 1199.9 sec	0.1 sec
Spare	2	-	-
Number of Measurements	5	0 – 18	1
Measurement Type	3	-	-
For N Measurement Blocks:			
Ranging Source ID	8	1 – 255	1
Issue of Data (IOD)	8	0 – 255	1
Carrier Correction	16	± 32767 mm	1 mm
Carrier Correction Rate	16	± 6553.4 mm/s	0.2 mm/s
σ_{pr_gnd} (Note 2)	8	0 - 51.0 mm	0.2 mm
B_1 (Note 1)	8	± 127 mm	1 mm
B_2 (Note 1)	8	± 127 mm	1 mm
B_3 (Note 1)	8	± 127 mm	1 mm
B_4 (Note 1)	8	± 127 mm	1 mm

Notes: ***1.*** *1000 0000 indicates the measurement is not available.*

2. *1111 1111 indicates the ranging source is invalid.*

Appendix D

PRELIMINARY AIRPORT PSEUDOLITE SIGNAL SPECIFICATION (INFORMATIVE)

Note: *This appendix remains unchanged from DO-246. Development of the airport pseudolite (APL) as an element of the LAAS and validation of the APL requirements are ongoing. This appendix is anticipated to be updated when the work has been completed.*

Appendix D—PRELIMINARY AIRPORT PSEUDOLITE SIGNAL SPECIFICATION (INFORMATIVE)

D.1 Introduction

This appendix defines the preliminary characteristics of the Signal-in-Space of the proposed ground-based augmentation APL.

The LAAS may use pseudo-satellites (Airport Pseudolites - APLs) to provide ranging signals that augment the GNSS. This signal specification defines the service to be provided by the APLs. It is written to satisfy the following objectives:

a. Define the ranging signal characteristics.

b. Define the signal data structure.

D.2 Signal Characteristics

The APL signal broadcast is designed to minimize GPS receiver hardware modifications. The basic signal characteristic is similar to GPS, using the same frequency and modulation technique, including a modified PRN code. In addition, the code phase timing is maintained close to GPS time to provide a ranging capability. In order to minimize interference to GPS ranging source signals, the APL signals are pulsed with a duty cycle of 0.02733.

D.2.1 Carrier Frequency

The LAAS APL broadcast consists of a single carrier frequency of 1575.42 MHz (GPS L1).

D.2.2 Spurious Transmissions

Spurious transmissions are at least 40 dB below the unmodulated carrier power.

D.2.3 Modulation

Bi-phase modulation is used for the code and the data. Message bits at a rate of 50 bits per second (bps) are modulo-2 added to the APL-code, which is then bi-phase shift-keyed (BPSK) modulated onto the carrier at a rate of 10.23 M-chips per second. Code/carrier frequency coherence is exactly maintained at a ratio of 1/154. The relationship between the APL Code and Data modulated on the carrier is maintained as described in the ICD-GPS-200C. The 50 bps data is synchronized with the 1.5 second APL-code S1 epochs.

D.2.4 Carrier Phase Noise

The phase noise spectral density of the signal is such that a phase locked loop with a one-sided noise bandwidth of 10 Hz will be able to track the carrier to an accuracy of 0.1 radians RMS.

D.2.5 Signal Spectrum

The broadcast signal is centered at the GPS L1 frequency of 1575.42 MHz. Ninety-nine percent of the broadcast power is in a 41 MHz bandwidth.

D.2.6 Carrier Frequency Stability

The short-term stability of the carrier frequency (square root of the Allan variance) at the input of the user's receiver antenna is less than 5×10^{-11} over 1 to 10 seconds, excluding the effects of Doppler.

D.2.7 Polarization

The broadcast signal is vertically polarized.

Note: Vertical polarization is specified to minimize the effects of multipath.

D.2.8 Pulse Sequence and Pulse Repetition Rate

The pulse sequence includes at least one pulse every millisecond. For the required low duty cycle, a relatively high pulse repetition rate results in relatively narrow pulses (on the order of a few microseconds). The pulsing sequence is defined to be transparent to the user receivers and Table D-1 summarizes the pulse sequence parameters. Details of the pseudo-random pulse sequence are documented in Appendix E.

Note: *A pseudorandom pulse sequence is used to prevent the user receiver from locking on to the pulse pattern. This pseudorandom sequence will result in a random pulse repetition rate. The average pulse repetition rate is sufficiently high (1997 pulses per second) so that the APL signal will appear to be continuous in the user's receiver post correlation signal processing, while appearing to be pulsed during wideband processing prior to correlation.*

Table D-1 Pulse Sequence Parameters

Pulse Sequence Parameter	Value
Pulse Sequence Length	1 second
Sequence Starting Time (relative to 1 second APL epochs)	(PRN mod 72) × 0.01 seconds
Pulse Sequence Clock	1 pulse slot per 140 APL code chips
Pulse Width	140 APL code chips ≈ 13.685 µsec
Pulse Intervals per Second	73,072 (last one is short with no pulse)
Pulses per Second	1997
Average Pulse Duty Cycle	(1997 × 140) / 10,230,000 ≈ 0.02733
Number of Pulses per ms	1.693 (average), 0 (min), 9 (max), σ = 1.693
Number of Pulses per 5 ms	10.035 (average), 0 (min), 29 (max), σ = 6.258
Number of Pulses per 10 ms	19.97 (average), 10 (min), 33 (max), σ = 4.443
Number of Pulses per 20 ms	39.94 (average), 30 (min), 53 (max), σ = 5.497

D.2.9 User Received Signal Levels

The average received power level (P_{ave}) into a 0 dBi Right-Hand-Circularly-Polarized (RHCP) antenna from a LAAS APL varies with distance from the APL as shown in Figure D-1. The minimum and maximum signal strength is TBD within the defined coverage volume.

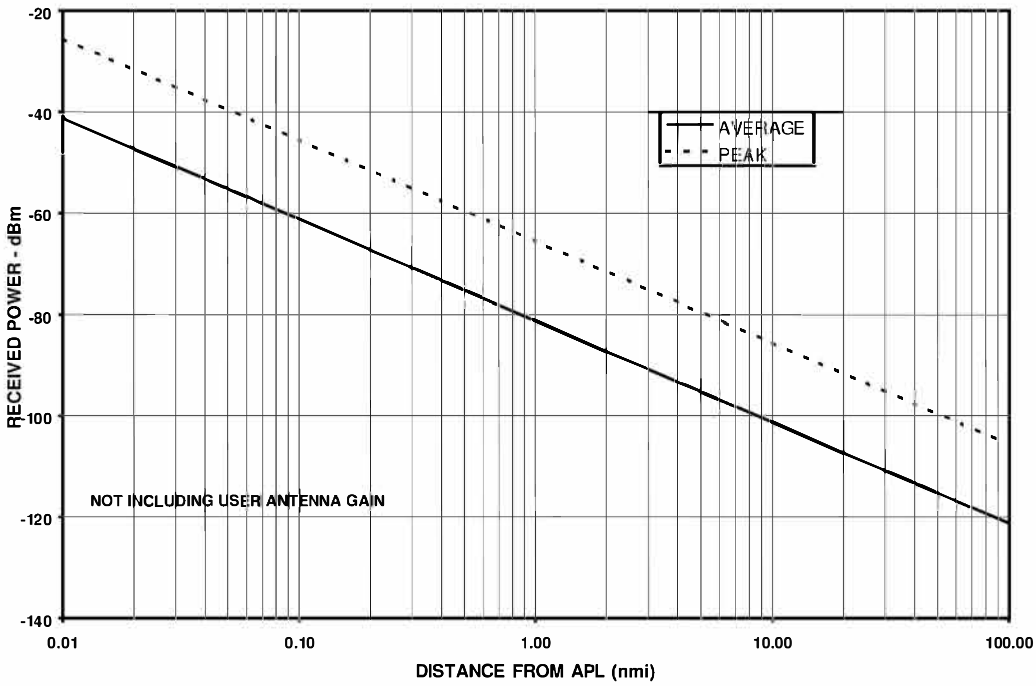

Figure D-1 Peak and Average APL Received Power, Not Including User Antenna Gain

D.2.10 Correlation Loss

Correlation loss is defined as the ratio of output powers from a perfect correlator for two cases:

a. the actual received APL signal correlated against a perfect unfiltered PN reference, or

b. a perfect unfiltered PN signal normalized to the same total power as the APL signal in case 1, correlated against a perfect unfiltered PN reference.

The correlation loss resulting from modulation imperfections and band-limiting is less than 1 dB.

D.2.11 Maximum Code Phase Deviation

The maximum uncorrected APL code phase of the broadcast signal is maintained within 1 second of GPS time.

D.3 APL-codes

The APL-codes are identified as follows:

a. One GPS-like week-long 10.23 Mchips/second PN code, and

b. Code phase delay with respect to the beginning of the GPS week in minutes.

The definition of code phase delay is an integer *N*, between 1 (one minute - 613,800,000 code-chips) and 10,079 minutes after the start of the GPS week, of which 72 integers (139 to 210 minutes) are used for APLs. (These 72 delays are referred to as PRN 139 - 210). Thus, the APL-code phase week starts *N* minutes after the start of the GPS week and ends *N* minutes after the end of the GPS week, at which time the APL-code reinitializes to the beginning of the week. APLs operating in the same region will all have different code phase delays.

D.3.1 APL-code Definition

The APL-code is a ranging code, APL(t), of 7 days in length at a chipping rate of 10.23 M-chips per second. The 7-day sequence is the modulo-2 sum of two sub-sequences referred to as S1 and $S2_{34}$; their lengths are 15,345,000 chips and 15,345,037 chips, respectively. The $S2_{34}$ sequence is an S2 sequence delayed by 34 chips.

D.3.1.1 Code Structure

The APL(t) pattern (APL-code) is generated by the modulo-2 summation of two PRN codes, S1(t) and S2(t - 34T), where T is the period of one APL-code chip and equals 1/ (1.023×10^7) seconds.

D.3.1.2 APL-code Generation

The APL patterns are the modulo-2 sum of two extended patterns clocked at 10.23 M-chips per second (S1 and $S2_{34}$), as shown in Figure D-2, which shows a functional APL-code mechanization. S1 itself is generated by the modulo-2 sum of the output of two 12-stage registers (S1A and S1B) short cycled to 4092 and 4093 chips respectively. When the S1A short cycles are counted to 3750, the S1 epoch is generated. The S1 epoch occurs each 1.5 seconds, after 15,345,000 chips of the S1 pattern have been generated. The polynomials for S1A and S1B, as referenced to the shift register input, are:

S1A: $1 + X^6 + X^8 + X^{11} + X^{12}$, and

S1B: $1 + X^1 + X^2 + X^5 + X^8 + X^9 + X^{10} + X^{11} + X^{12}$

Samples of the relationship between shift register taps and the exponents of the corresponding polynomial, referenced to the shift register input, are shown in Figure D-3, Figure D-4, Figure D-5 and Figure D-6.

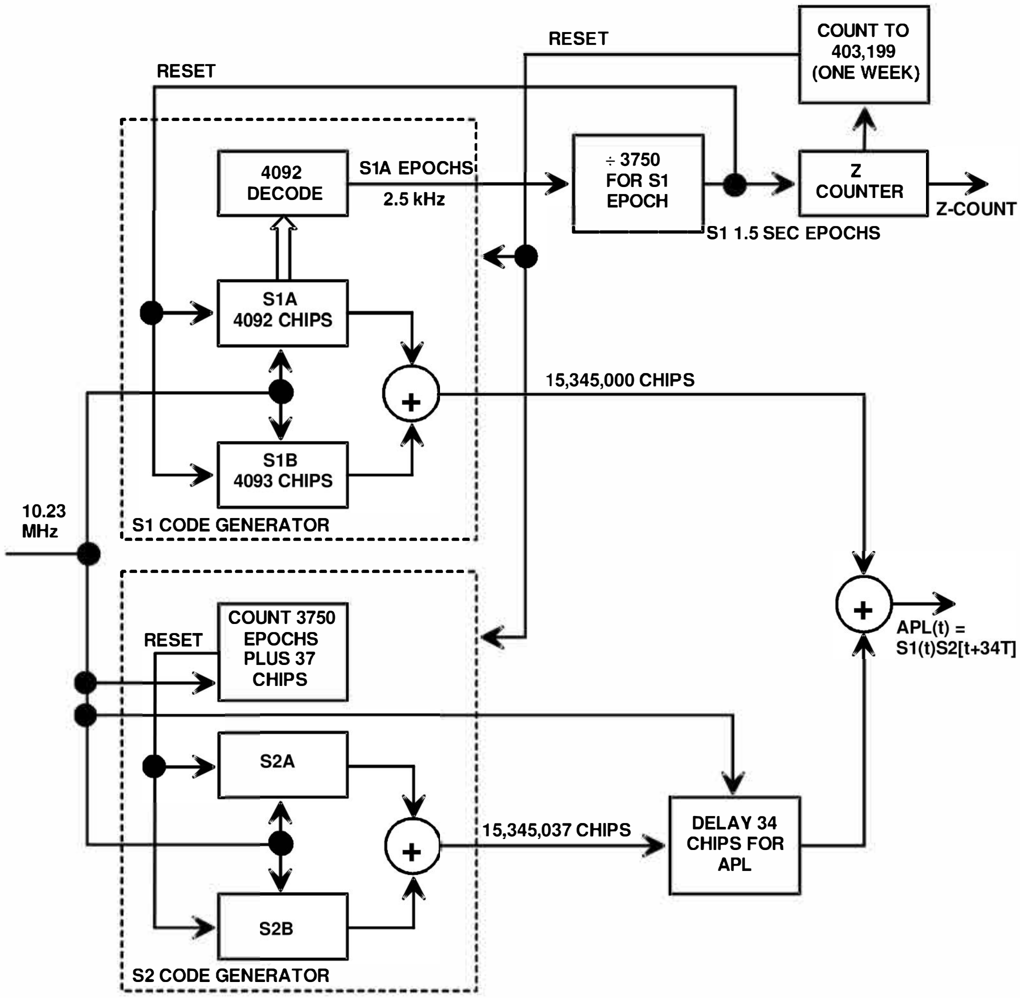

Figure D-2 APL-code Generation

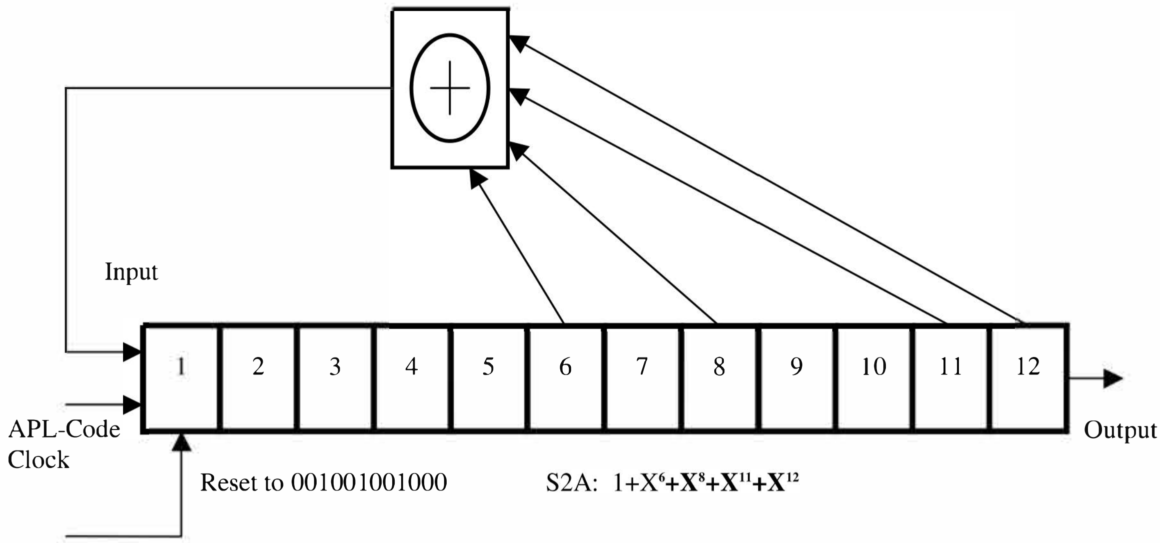

Figure D-3 S1A Shift Register Generator Configuration

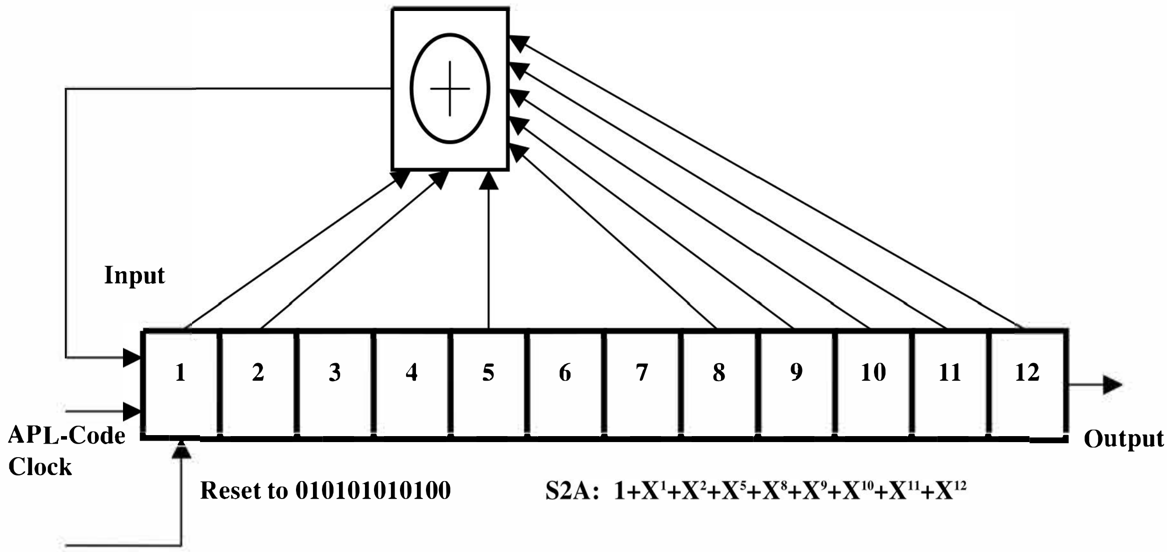

Figure D-4 S1B Shift Register Generator Configuration

The state of each generator can be expressed as a code vector word which specifies the binary sequence constant of each register as follows: (a) the vector consists of the binary state of each stage of the register, (b) the stage 12 value appears at the left followed by the values of the remaining states in order of descending stage numbers and (c) the shift direction is from lower to higher stage number with stage 12 providing the current output. This code vector convention represents the present output and 11 future outputs in sequence. Using this convention, at each S1 epoch, the S1A shift register is initialized to code vector 001001001000 and the S1B shift register is initialized to code vector 010101010100. The first chip of the S1A sequence and the first chip of an S1B sequence occur simultaneously in the first chip interval of any S1 period.

The natural 4095 chip cycles of these generating sequences are shortened to cause precession of the S1B sequence with respect to the S1A sequence during subsequent cycles of the S1A sequence in the S1 period. Reinitialization of the S1A shift register produces a 4092 chip sequence by omitting the last 3 chips (001) of the natural 4095 chip S1A sequence. Reinitialization of the S1B shift register produces a 4093 chip sequence by omitting the last 2 chips (01) of the natural 4095 chip S1B sequence. This results in the phase of the S1B sequence lagging by one chip for each S1A cycle in the S1 period.

The S1 period is defined as 3750 S1A cycles (15,345,000 chips) which is not an integer number of S1B cycles. To accommodate this situation, the S1B shift register is held in the final state (chip 4093) of its 3749th cycle. It remains in this state until the S1A shift register completes its 3750th cycle (343 additional chips). The completion of the 3750th S1A cycle establishes the next S1 epoch, which reinitializes both the S1A and S1B shift registers starting a new S1 cycle.

The $S2_{34}$ sequence is generated by first producing an S2 sequence and then delaying it by 34 chips. The $S2_{34}$ sequence is then Modulo-2 added to the S1 sequence thereby producing the APL(t).

The S2A and S2B shift registers, used to generate S2, operate in a similar manner to the S1A and S1B shift registers. They are short-cycled, S2A to 4092 ant S2B to 4093, so that they have the same relative precession rate as the S1 shift registers. S2A epochs are counted to include 3750 cycles and S2B is held in the last state at 3749 cycle until S2A completes its 3750th cycle. The polynomials for S2A and S2B, as referenced to the shift register input, are:

S2A: $1 + X^1 + X^3 + X^4 + X^5 + X^7 + X^8 + X^9 + X^{10} + X^{11} + X^{12}$, and

S2B: $1 + X^2 + X^3 + X^4 + X^8 + X^9 + X^{12}$

The initialization vector for S2A is 100100100101 and for S2B is 010101010100.

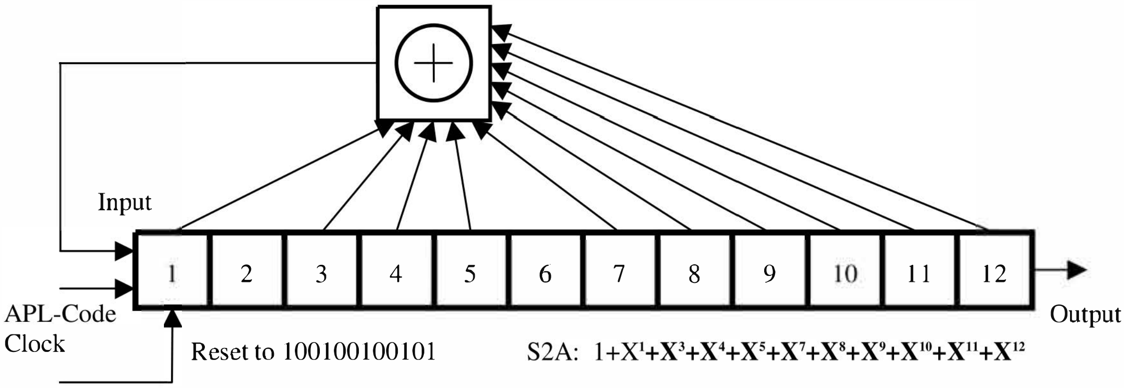

Figure D-5 S2A Shift Register Generator Configuration

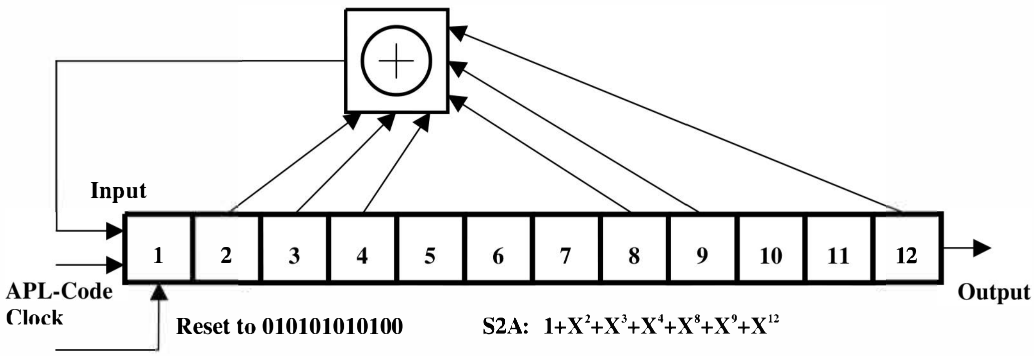

Figure D-6 S2B Shift Register Generator Configuration

The S2A and S2B epochs are made to precess with respect to the S1A and S1B epochs by causing the S2 period to be 37 chips longer than the S1 period. When S2A is in the last state of its 3750th cycle and S2B is in the last state of its 3749th cycle, their transitions to their respective initial states are delayed by 37 chip time intervals.

At the beginning of the APL week, S1A, S1B, S2A, and S2B shift registers are initialized to produce the first chip of the week. The precession of the shift registers with respect to S1A continues until the last S1A period of the APL week interval. During this particular S1A period, S1B, S2A, and S2B are held when reaching the last state of their respective cycles until that S1A cycle completes (see Table D-2). At this point, all four shift registers are initialized and provide the first chip of the new week.

Signal component timing is shown in Figure D-7, while the end-of-week reset timing and the final code vector states are given in Table D-2 and Table D-3, respectively.

D.4 LAAS APL Signal Data Contents and Formats

D.4.1 Data Rate

The data rate is 50 bits per second.

Table D-2 APL-Code Reset Timing

(Last 400 µsec of 7 Day Period)

Code Chip			
S1A-Code	S1B-Code	S2A-Code	S2B-Code
1	345	1070	967
.	.	.	.
.	.	.	.
.	.	.	.
3023	3367	4092	3989
.	.	.	.
.	.	.	.
.	.	.	.
3127	3471	4092	4093
.	.	.	.
.	.	.	.
.	.	.	.
3749	4093	4092	4093
.	.	.	.
.	.	.	.
.	.	.	.
4092*	4093	4092	4093
*Last Chip of week			

Table D-3 Final Code Vector States

	S1A-Code	S1B-Code	S2A-Code	S2B-Code
Chip No. Vector State	4091 100010010010	4092 100101010101	4091 111001001001	4092 000101010101
Chip No. Vector State	4092 000100100100	4093 001010101010	4092 110010010010	4093 001010101010
Vector State for 1^{st} Chip following Epoch	001001001000	010101010100	100100100101	010101010100
Note: *First Chip in each sequence is output bit whose leading edge occurs simultaneously with the epoch.*				

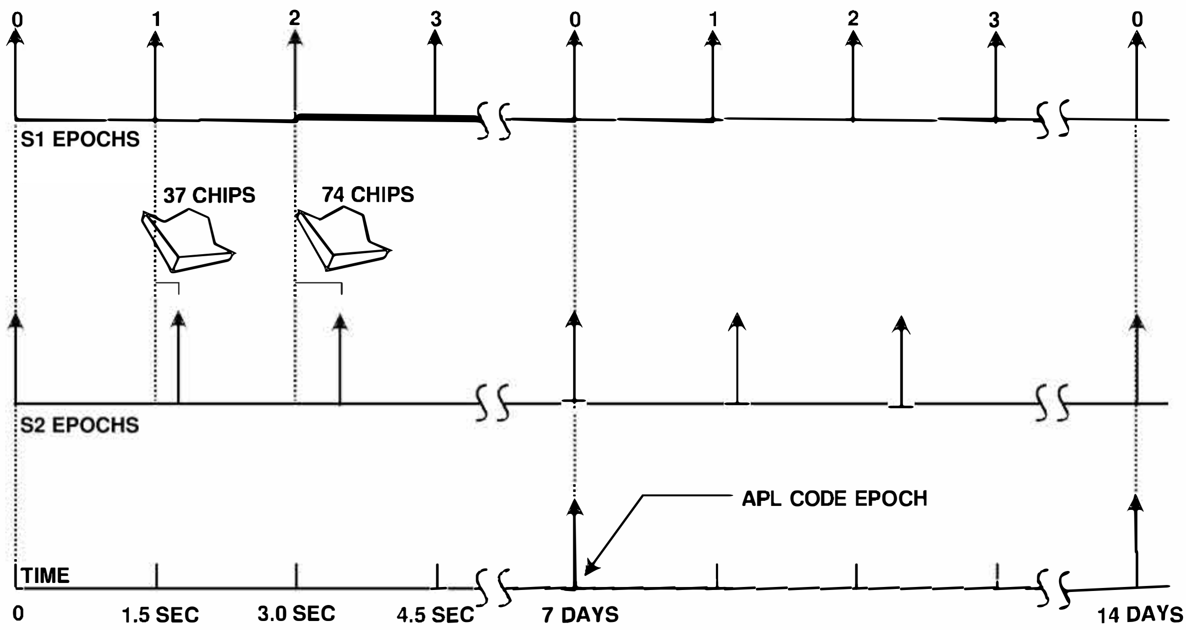

Figure D-7 APL-Code Signal Component Timing

D.4.2 Timing

LAAS Network Time is defined as that which is maintained, after corrections, close to GPS system time, within the overall LAAS performance requirements. It is noted that, when using differential corrections, the user's solution for time will be with respect to GPS system time. If corrections are not applied, then the solution will be with respect to a composite GPS/LAAS APL Time, and the resulting accuracy will be affected by the difference between the two. The APL code phase is an integer *N* minutes delayed with respect to that time.

D.4.3 Tropospheric Delay Models

Because the range between the APL to the LAAS Ground Station and the user, which are entirely in the troposphere, are different, both the ground station and the user must apply a troposphere correction in addition to the differential correction. Thus, a special tropospheric delay model applies to correct APL ranging measurements. This model is of the form, in meters,

$$\delta R_{Tr} = N_{APL} \times (1 - \Delta h_u / h_0) \times R \times 10^{-6}$$

where N_{APL} is the tropospheric refractivity along the signal path, R is the range (in meters) between the APL and the user, h_0 is the scale height and Δh_u is the altitude (in meters) of the user relative to the APL. Note that Δh_u can be negative if the APL is higher than the user, in which case the parenthetical quantity will be greater than one, as it should be. A tropospheric index, for computing the tropospheric refractivity, and the scale height are broadcast as part of the Reference Point Data message (Message Type 2, see Section 2.4.4).

D.4.4 Acquisition Information

Signal acquisition can be accomplished by the user via direct APL-code acquisition. This is possible because APL timing is maintained to within 71.5 milliseconds of LAAS Network Time, and the APL position is known to within less than a meter via the VHF Data Link (i.e., from the data in Message Type 3).

Although direct APL-code acquisition provides exact data timing for data acquisition, the code delay is provided in the APL 50 bps broadcast message to verify correct code acquisition.

D.4.5 Block Data Format

The block format and definition for the 50 bits per second data rate is fixed for a given APL as shown in Figure D-8. The single data block is 25 bits long and is repeated every 0.5 seconds. The block starts with a 14 bit integer word defining the code delay (1 - 10079), followed by 11 - "1s". These "1s" provide for full-integer carrier phase cycle ambiguity resolution and an unambiguous code delay. Only 72 code delays in the range of 139 to 210 is used for APLs.

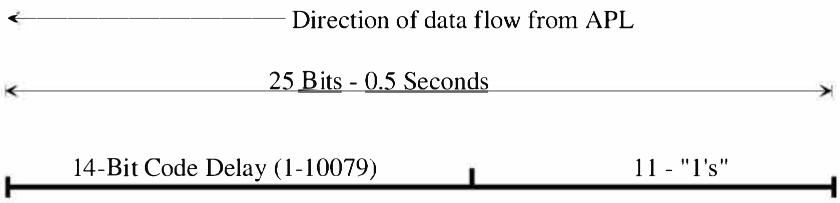

Figure D-8 Message Block Format

The 14-bit code delay starts at bit 0 of the 25-bit message, of which every third one is lined up with APL S1 epoch.

Appendix E

PRELIMINARY APL PULSE SEQUENCE DEFINITION

Note: *This appendix remains unchanged from DO-246. Development of the airport pseudolite (APL) as an element of the LAAS and validation of the APL requirements are ongoing. This appendix is anticipated to be updated when the work has been completed.*

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Appendix E—PRELIMINARY APL PULSE SEQUENCE DEFINITION

E.1 APL Pulse Sequence

Figure E-1 presents a block diagram of the pseudorandom pulse generator. It is based upon a 19-stage maximal length PRN shift register clocked at a rate of 511.500 kHz. If it were allowed to finish its entire pseudorandom sequence, it would start over at about once every 1.025 seconds. However, it is short-cycled at 1-second APL epochs. A pulse is generated every time there is a string of exactly 6-1s at the output of the shift register, which occurs 1997 times in one second. That event triggers a pulse output during the next 140-Wide Band chip slot generated from the pulse sequence clock running at 511,500/7 Hz.

Clocking pre-stored bits out of RAM can also generate the pulses. This can be accomplished by storing 73,072 bits in RAM with 1997 bits set to 1, and clocking them out at a rate of 511,500/7 bits per second. Anytime a 1-bit is clocked out a pulse is generated. The times, after the start of the sequence, of bits set to 1 are listed in Table E-1a.

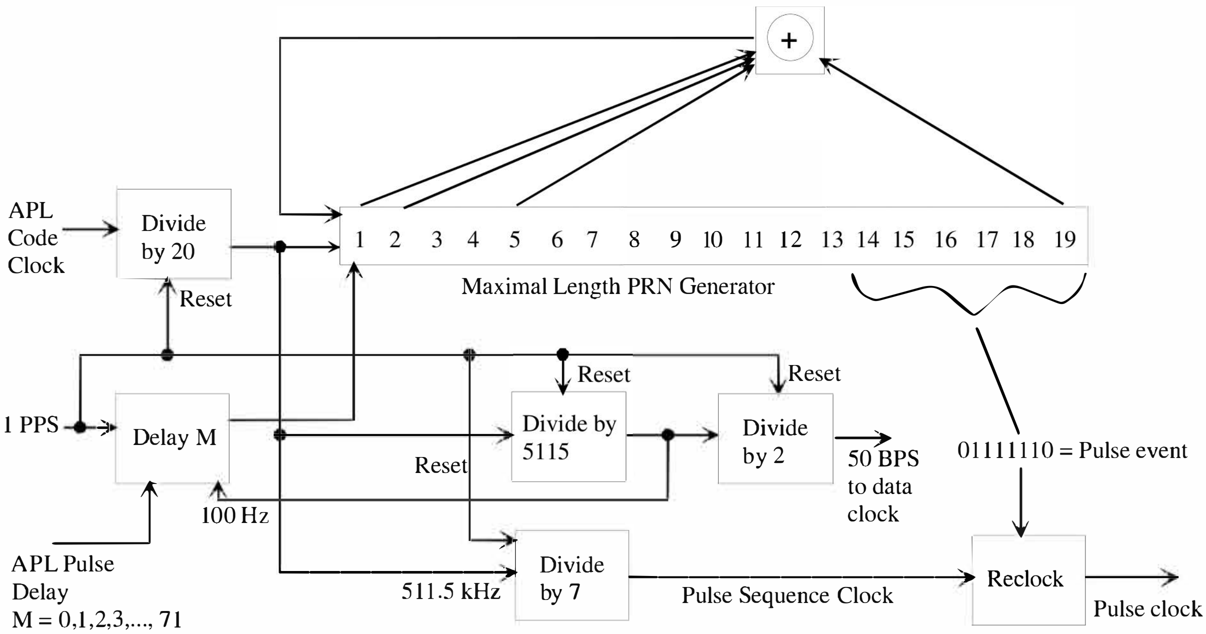

Figure E-1 APL Pulse Sequence Generator

The distribution of pulse timing is shown in Figure E-2, plotted against the number of pulse intervals between the leading edges of the pulses.

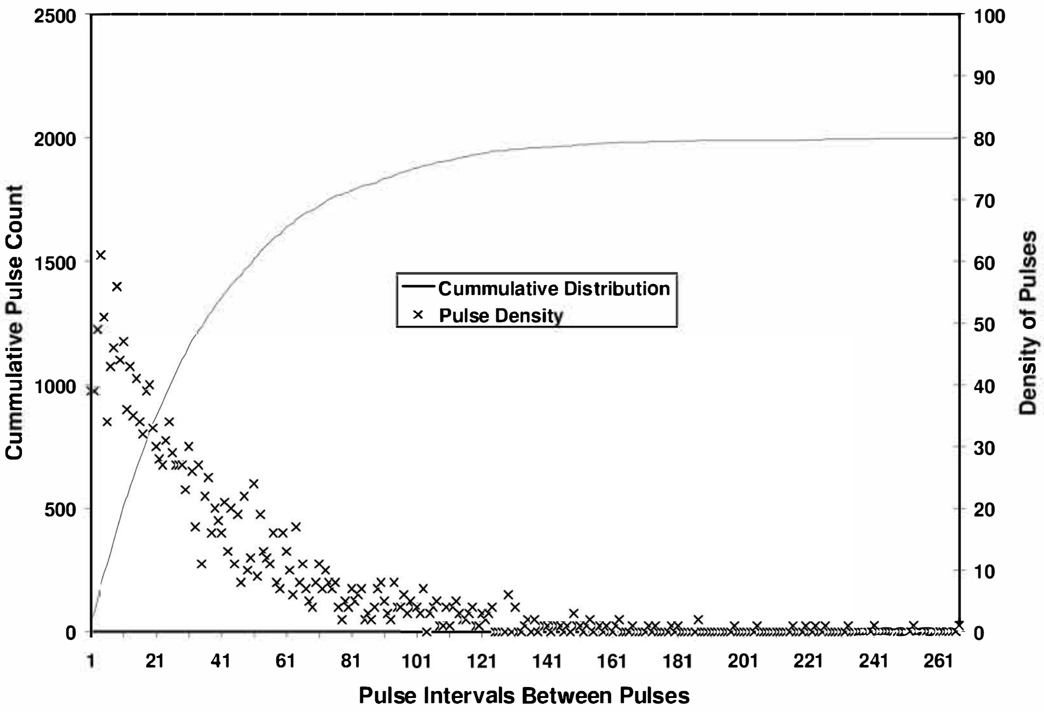

Figure E-2 Distribution of Pulses

Table E-1a Pulse Times After Start of Sequence (First 500 Pulses)

Pulse	Pulse Interval								
	0	1	2	3	4	5	6	7	8	9
1	42	1697	3391	4729	6495	8396	10418	11939	13903	15592
2	110	1708	3412	4766	6504	8397	10432	11940	13916	15686
3	144	1735	3479	4847	6557	8408	10459	11971	13928	15692
4	152	1740	3492	4912	6584	8412	10516	12009	13967	15743
5	173	1801	3517	5036	6683	8420	10522	12045	13972	15796
6	207	1827	3577	5057	6684	8472	10528	12050	13975	15827
7	218	1859	3584	5074	6702	8492	10615	12086	14011	15847
8	222	1891	3593	5079	6721	8531	10676	12114	14042	15876
9	268	2022	3629	5084	6732	8551	10724	12148	14086	15893
10	276	2064	3634	5187	6760	8553	10754	12210	14104	15938
11	318	2096	3636	5231	6778	8564	10776	12224	14183	15942
12	343	2104	3659	5234	6821	8585	10817	12240	14198	15995
13	344	2123	3675	5352	6853	8613	10875	12280	14216	16005
14	352	2128	3689	5366	6948	8621	10943	12354	14241	16011
15	466	2136	3699	5420	6952	8631	10959	12410	14322	16020
16	504	2163	3733	5461	7049	8640	10985	12416	14343	16114
17	519	2169	3773	5508	7053	8747	10987	12434	14347	16162
18	524	2200	3812	5519	7066	8750	11006	12443	14371	16187
19	569	2329	3819	5531	7136	8776	11053	12462	14388	16192
20	576	2357	3841	5542	7167	8780	11104	12490	14401	16251
21	601	2413	3853	5558	7170	8781	11131	12602	14423	16275
22	655	2428	3880	5584	7204	8813	11147	12603	14442	16308
23	696	2439	3883	5673	7210	8845	11160	12701	14449	16404
24	739	2526	3895	5712	7214	8959	11171	12716	14606	16464
25	805	2530	3943	5726	7217	8970	11174	12774	14643	16477
26	844	2567	3959	5755	7272	8992	11204	12775	14695	16487
27	975	2574	3992	5759	7342	9030	11207	12866	14710	16502
28	991	2599	4015	5819	7398	9059	11235	12976	14728	16569
29	1002	2613	4054	5846	7418	9084	11266	13012	14750	16593
30	1011	2666	4069	5850	7577	9146	11274	13022	14767	16634
31	1088	2699	4095	5931	7596	9180	11310	13131	14769	16643
32	1148	2728	4119	5967	7704	9291	11317	13140	14778	16671
33	1169	2776	4128	6033	7712	9312	11322	13261	14786	16744
34	1172	2808	4177	6065	7785	9323	11330	13378	14806	16797
35	1192	2846	4200	6113	7862	9430	11360	13396	14816	16887
36	1242	2888	4233	6129	7913	9484	11422	13411	14829	16888
37	1246	2965	4257	6148	7928	9487	11440	13415	14856	16913
38	1342	2966	4353	6201	7940	9489	11449	13476	14865	17042
39	1404	2975	4375	6236	7945	9712	11486	13626	15046	17044
40	1440	2985	4400	6238	8019	9886	11570	13661	15140	17091
41	1462	3028	4445	6281	8033	9905	11573	13674	15163	17157
42	1506	3029	4466	6284	8086	9968	11615	13714	15284	17175
43	1521	3067	4523	6287	8122	9976	11655	13725	15330	17184
44	1534	3080	4559	6305	8145	9980	11755	13730	15332	17199
45	1536	3097	4582	6354	8191	10129	11760	13743	15438	17217
46	1541	3149	4586	6369	8239	10152	11768	13799	15448	17239
47	1550	3159	4595	6394	8264	10184	11858	13819	15499	17276
48	1581	3242	4678	6411	8337	10211	11886	13833	15539	17295
49	1621	3245	4680	6471	8339	10340	11898	13849	15587	17311
50	1635	3267	4716	6482	8367	10382	11918	13900	15590	17408

Table E-1b Pulse Times After Start of Sequence (Second 500 Pulses)

Pulse	Pulse Interval								
	0	1	2	3	4	5	6	7	8	9
501	17411	18982	21016	22875	24713	26408	28614	30315	32225	34057
502	17420	19084	21080	22879	24726	26451	28615	30358	32228	34062
503	17433	19135	21106	22890	24749	26482	28689	30365	32303	34128
504	17463	19228	21112	22913	24779	26487	28826	30398	32304	34172
505	17485	19270	21142	22927	24836	26537	28870	30423	32335	34189
506	17489	19321	21143	22943	24851	26542	28962	30431	32392	34259
507	17496	19378	21410	22963	24855	26561	29006	30536	32437	34286
508	17504	19463	21439	22976	24882	26590	29009	30561	32441	34326
509	17569	19483	21500	22994	24913	26641	29049	30565	32452	34336
510	17574	19504	21504	23118	24949	26712	29081	30593	32464	34362
511	17608	19508	21519	23133	25098	26725	29087	30621	32466	34491
512	17618	19533	21573	23147	25117	26790	29092	30640	32474	34560
513	17622	19542	21648	23211	25198	26903	29160	30666	32492	34572
514	17707	19552	21654	23452	25200	26935	29193	30690	32518	34610
515	17726	19561	21657	23491	25215	27015	29203	30695	32525	34637
516	17744	19591	21696	23640	25233	27078	29241	30711	32533	34657
517	17748	19621	21742	23646	25250	27095	29340	30864	32546	34679
518	17814	19646	21779	23664	25351	27127	29353	30873	32638	34732
519	17832	19653	21794	23693	25375	27130	29397	30885	32647	34742
520	17896	19662	21862	23732	25428	27149	29442	30934	32703	34746
521	17908	19682	21872	23787	25431	27190	29447	30941	32708	34776
522	17968	19692	22051	23791	25503	27252	29568	30985	32839	34855
523	17979	19855	22065	23801	25514	27255	29584	31047	32846	34870
524	18007	19887	22141	23807	25558	27273	29617	31102	32897	34902
525	18015	19907	22212	23812	25565	27283	29620	31124	32924	34975
526	18059	19942	22253	23843	25604	27286	29640	31231	32951	34982
527	18121	19949	22254	23846	25642	27295	29651	31240	32956	34987
528	18179	19971	22311	23907	25657	27304	29694	31286	33069	35035
529	18192	19978	22327	23953	25662	27364	29699	31360	33104	35107
530	18209	20083	22349	23968	25679	27379	29775	31384	33108	35126
531	18214	20197	22356	24071	25724	27465	29825	31412	33182	35127
532	18252	20246	22373	24088	25728	27537	29832	31431	33253	35143
533	18267	20250	22437	24102	25743	27654	29862	31495	33257	35186
534	18317	20267	22470	24152	25827	27735	29900	31511	33317	35190
535	18330	20337	22478	24212	25911	27764	29955	31556	33380	35198
536	18384	20420	22480	24232	25932	27793	29965	31583	33503	35200
537	18478	20461	22489	24244	25942	27809	29976	31659	33554	35232
538	18488	20556	22509	24261	25960	27836	29977	31726	33557	35240
539	18579	20596	22540	24307	26024	27975	29984	31765	33636	35277
540	18594	20600	22570	24364	26042	27995	30003	31807	33646	35310
541	18595	20617	22659	24383	26073	28182	30015	31817	33671	35382
542	18620	20625	22720	24406	26109	28192	30036	31833	33673	35393
543	18735	20690	22726	24524	26146	28214	30078	31841	33685	35413
544	18786	20696	22737	24526	26156	28349	30112	31844	33890	35418
545	18836	20748	22739	24550	26176	28401	30141	31911	33901	35444
546	18842	20806	22742	24556	26198	28435	30144	31956	33958	35478
547	18870	20811	22765	24570	26205	28508	30250	31961	33960	35640
548	18901	20866	22784	24577	26221	28573	30251	32007	33968	35648
549	18915	20935	22790	24591	26242	28582	30267	32091	33990	35656
550	18922	20974	22841	24644	26337	28590	30285	32148	34016	35690

Table E-1c Pulse Times After Start of Sequence (Third 500 Pulses)

Pulse	Pulse Interval								
	0	1	2	3	4	5	6	7	8	9
1001	35722	37593	39383	41396	43055	44804	46344	48283	50258	52537
1002	35770	37598	39440	41420	43105	44868	46388	48295	50292	52550
1003	35780	37632	39445	41429	43151	44889	46443	48329	50328	52558
1004	35784	37648	39458	41433	43158	44896	46460	48336	50347	52573
1005	35816	37678	39592	41443	43163	44899	46473	48378	50368	52590
1006	35905	37689	39609	41483	43179	44904	46551	48409	50390	52607
1007	35956	37716	39689	41488	43196	44916	46605	48453	50476	52659
1008	36047	37748	39733	41505	43208	44965	46662	48465	50495	52710
1009	36055	37765	39790	41524	43263	45059	46690	48491	50497	52735
1010	36092	37772	39793	41576	43277	45078	46734	48707	50560	52754
1011	36110	37800	39811	41593	43310	45084	46752	48777	50613	52810
1012	36162	37833	39820	41595	43349	45086	46779	48801	50642	52844
1013	36226	37921	39843	41599	43362	45088	46806	48809	50875	52856
1014	36446	37925	39869	41624	43372	45102	46818	48823	50876	52923
1015	36504	37941	39903	41627	43397	45116	46839	48828	50891	52930
1016	36521	37950	39961	41673	43435	45130	46873	48876	50910	53033
1017	36552	38047	39969	41746	43437	45151	46910	48947	50939	53037
1018	36584	38137	40076	41757	43442	45261	46941	48957	51000	53077
1019	36591	38173	40174	41857	43474	45364	46954	49024	51053	53170
1020	36596	38182	40182	41911	43558	45407	46982	49065	51077	53180
1021	36608	38222	40210	41917	43562	45409	47002	49079	51195	53193
1022	36625	38323	40274	41936	43570	45466	47010	49152	51267	53236
1023	36631	38340	40278	41980	43580	45522	47026	49227	51281	53246
1024	36647	38365	40326	41994	43585	45549	47047	49236	51329	53265
1025	36686	38396	40418	42000	43596	45574	47048	49262	51342	53269
1026	36767	38425	40445	42029	43621	45577	47060	49285	51349	53393
1027	36787	38467	40456	42060	43628	45594	47160	49386	51385	53402
1028	36788	38469	40475	42076	43639	45670	47166	49395	51398	53406
1029	36794	38568	40486	42145	43713	45713	47175	49400	51499	53424
1030	36799	38650	40527	42215	43761	45734	47226	49517	51511	53442
1031	36855	38716	40593	42235	43784	45735	47317	49522	51518	53481
1032	36859	38756	40651	42236	43796	45747	47341	49551	51568	53543
1033	36862	38781	40682	42267	43799	45762	47400	49623	51639	53645
1034	36873	38793	40822	42454	43801	45768	47470	49642	51806	53659
1035	36876	38806	40825	42474	43834	45834	47556	49646	51828	53695
1036	36899	38859	40859	42495	43878	45863	47558	49665	51948	53775
1037	36900	38890	40881	42500	43943	45910	47578	49681	51952	53779
1038	36989	38910	40963	42510	43964	45931	47602	49688	52048	53782
1039	37004	38952	40992	42516	44074	45963	47605	49705	52124	53790
1040	37111	39055	41068	42533	44103	45968	47750	49742	52159	53816
1041	37169	39064	41099	42599	44185	46008	47810	49769	52179	53880
1042	37171	39072	41122	42625	44233	46105	47825	49829	52183	53998
1043	37182	39090	41164	42626	44311	46106	47944	49865	52247	54077
1044	37221	39141	41192	42656	44416	46167	47973	49880	52308	54159
1045	37258	39197	41242	42694	44487	46175	47977	49934	52398	54210
1046	37329	39201	41266	42723	44571	46177	48033	50063	52435	54219
1047	37362	39260	41295	42757	44577	46181	48075	50077	52448	54256
1048	37374	39268	41309	42840	44636	46207	48140	50084	52461	54304
1049	37474	39351	41318	42859	44682	46214	48242	50225	52515	54307
1050	37495	39360	41357	43013	44772	46320	48251	50240	52516	54406

Table E-1d **Pulse Times After Start of Sequence (Last 497 Pulses)**

Pulse	Pulse Interval								
	0	1	2	3	4	5	6	7	8	9
1501	54431	55888	57615	59794	61844	63982	66003	67791	69476	71578
1502	54464	55917	57642	59813	62007	63999	66047	67826	69511	71587
1503	54494	55981	57696	59859	62032	64105	66184	67838	69614	71641
1504	54500	56029	57705	59878	62116	64194	66200	67853	69726	71688
1505	54501	56051	57724	59888	62122	64288	66245	67888	69756	71699
1506	54614	56115	57733	59900	62156	64337	66246	67941	69764	71730
1507	54624	56259	57777	59934	62174	64341	66252	67974	69777	71753
1508	54646	56279	57782	59998	62246	64387	66327	68009	69840	71865
1509	54649	56340	57789	60044	62267	64395	66340	68021	69858	71867
1510	54659	56450	57817	60069	62290	64405	66366	68137	69925	71893
1511	54719	56475	57833	60089	62306	64476	66386	68142	69934	71930
1512	54766	56514	57968	60172	62338	64503	66420	68177	69947	71934
1513	54775	56532	58032	60215	62359	64701	66422	68178	69957	72007
1514	54872	56583	58051	60254	62418	64726	66426	68228	69958	72015
1515	54890	56628	58124	60269	62671	64789	66428	68239	69995	72090
1516	54902	56649	58131	60350	62690	64792	66436	68253	70074	72127
1517	54927	56673	58150	60361	62735	64905	66465	68299	70107	72130
1518	54936	56677	58181	60437	62777	64915	66477	68374	70222	72168
1519	54959	56702	58304	60475	62790	64959	66500	68377	70276	72198
1520	54968	56752	58530	60529	62796	64978	66531	68436	70364	72370
1521	55017	56823	58581	60577	62822	65031	66544	68451	70435	72384
1522	55025	56824	58584	60671	62844	65038	66554	68456	70482	72406
1523	55029	56862	58597	60802	62868	65043	66576	68486	70539	72518
1524	55057	56885	58604	60843	62923	65061	66705	68602	70554	72544
1525	55070	56895	58635	60856	62945	65073	66795	68605	70624	72572
1526	55097	56906	58664	60880	62947	65100	66835	68649	70665	72583
1527	55127	56921	58670	60977	62958	65116	66853	68697	70727	72609
1528	55153	56996	58698	60995	63019	65165	66899	68734	70787	72623
1529	55181	57053	58786	61004	63037	65241	66931	68750	70809	72644
1530	55204	57065	58805	61147	63117	65243	66942	68784	70824	72670
1531	55293	57091	58862	61182	63157	65279	66952	68832	70898	72700
1532	55335	57144	58874	61210	63183	65330	66959	68878	70904	72710
1533	55348	57151	58898	61269	63296	65334	66966	68901	70916	72734
1534	55396	57168	58962	61301	63344	65345	66975	68944	70917	72787
1535	55420	57192	58974	61354	63367	65386	67016	68995	70918	72790
1536	55429	57223	58983	61376	63377	65423	67071	69001	70943	72805
1537	55438	57272	59002	61397	63413	65447	67122	69002	70967	72828
1538	55443	57323	59003	61434	63466	65448	67204	69032	71005	72879
1539	55509	57348	59159	61445	63539	65513	67294	69046	71039	72892
1540	55518	57352	59186	61447	63540	65550	67310	69088	71099	72907
1541	55567	57381	59212	61598	63558	65587	67398	69242	71139	72931
1542	55578	57405	59334	61612	63657	65734	67439	69253	71181	72967
1543	55604	57451	59345	61630	63671	65742	67464	69261	71188	72971
1544	55699	57475	59405	61676	63684	65776	67520	69270	71249	72975
1545	55705	57512	59466	61683	63695	65870	67610	69334	71257	72986
1546	55747	57517	59490	61717	63742	65903	67641	69357	71272	73014
1547	55767	57546	59531	61728	63762	65951	67643	69378	71395	73045
1548	55787	57555	59620	61737	63865	65971	67698	69433	71517	
1549	55790	57559	59648	61803	63902	65985	67728	69444	71532	
1550	55814	57611	59703	61804	63952	66001	67765	69458	71536	

Appendix F

PRELIMINARY GROUND BASED RANGING SOURCE DATA MESSAGE DEFINITION (INFORMATIVE)

Note: *This appendix remains unchanged from DO-246. Development of the airport pseudolite (APL) as an element of the LAAS and validation of the APL requirements are ongoing. This appendix is anticipated to be updated when the work has been completed.*

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Appendix F—PRELIMINARY GROUND BASED RANGING SOURCE DATA MESSAGE DEFINITION (INFORMATIVE)

F.1 Variable Definition

The GBRS provides additional ranging information to improve the availability of the LAAS system. This message format provides additional detail on the proposed APL implementation.

F.1.1 Variable Definition

Airport Pseudolite (APL) Clock Offset: represents the APL clock offset in meters. It is applied in the same sense that the ranging source clock offset provided in the GPS Navigation Message is applied.

Airport Pseudolite (APL) Health: represents the APL health and is TBD.

Airport Pseudolite (APL) IOD: represents the APL IOD. It also serves as the reference time for the APL Clock Offset. Its resolution is 1 second with a range of 240 seconds, rolling over 15 times per GPS hour, and synchronized with the GPS hour.

Airport Pseudolite (APL) Ranging Source ID: contains the identity of the ground ranging source for which data is applicable. There are 72 channels each defined as *N**61,380,000 chips (*N* minutes) offset from the current TOW of the APL code. The ID corresponds directly to N. The range is 1-255, where 1 is specified by "0000 0001" and "0000 0000" is not used. ID's 139-210 are reserved for ranging source IDs (PRN) consistent with the Local Area Augmentation System (LAAS).

Latitude: is the latitude of the reference point and is defined in WGS-84 coordinates and transmitted in arc seconds. The most significant bit is the sign bit:

0 = positive (Northern Hemisphere)
1 = negative (Southern Hemisphere)

Longitude: is the longitude of the reference point and is defined in WGS-84 coordinates and transmitted in arc seconds. The most significant bit is the sign bit:

0 = positive (Eastern Hemisphere)
1 = negative (Western Hemisphere)

Vertical Ellipsoid Offset: is the distance along the vector normal to the WGS-84 Ellipsoid to the data point of interest.

F.2 Message Table – GBRS Data

Table F-1 Proposed Format of GBRS Data — Message Type 3

Data Content	Bits Used	Range of Values	Resolution
APL Range Source ID	8	139 - 210 min	1 min
APL Clock Offset	32	± 21,474,181.12 m	0.01 m
APL Clock Drift	16	± 32.767 m/s	0.1 mm/s
APL IOD (reference time)	8	240 sec	1 sec
Latitude	40	± 90.0 °	2.0 μarcsec
Longitude	40	± 180.0 °	2.0 μarcsec
Vertical Ellipsoid Offset	24	± 83,886.07 m	0.01 m

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Appendix G

GLOSSARY, ABBREVIATIONS AND ACRONYMS

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Appendix G—GLOSSARY, ABBREVIATIONS AND ACRONYMS

AC — Advisory Circular

AGC — Automatic Gain Control

APL — Airport Pseudolite

CFR — Code of Federal Regulations

CRC — Cyclic Redundancy Check

Differential GNSS (DGNSS) — Differential GNSS is an augmentation, the purpose of which is to determine position errors at one or more known locations and subsequently transmit derived information to other GNSS receivers in order to enhance the accuracy, integrity, and availability of the position estimate. (Source: Adapted from the ICAO FANS GNSS Technical Subgroup.)

D8PSK — Differential 8-state Phase Shift Keying

FCC — Federal Communications Commission

FEC — Forward Error Correction

Fictitious Threshold Point (FTP) — The FTP is a point functionally equivalent to a Landing Threshold Point, except that the FTP is not located on the runway centerline.

Final Approach Segment (FAS) — The straight line segment that prescribes the three-dimensional geometric path in space that an aircraft is supposed to fly on final approach.

Flight Path Alignment Point (FPAP) — The FPAP is used in conjunction with the LTP/FTP and the geometric center of the WGS-84 ellipsoid to define the geodesic plane of a precision final approach, landing and flight path. The FPAP is typically located at or near the runway stop end. The FPAP may have the same latitude/longitude as the LTP/FTP for the approach to the opposite end of the same runway.

Glide Path Angle (GPA) — The glide path angle is an angle, defined at the Threshold Crossing Point (directly above the LTP/FTP at a height equal to the TCH), that establishes the intended descent gradient for the final approach flight path of a precision approach procedure. It is measured between the final approach path and the plane containing the LTP/FTP that is parallel to the tangent to the WGS-84 ellipsoid.

Glide Path Intercept Point (GPIP) — The GPIP is the point at which the extension of the final approach path intercepts the plane containing the LTP/FTP that is parallel to the tangent to the WGS-84 ellipsoid at the LTP/FTP.

Global Navigation Satellite System (GNSS) — GNSS is a world-wide position, velocity, and time determination system, that includes one or more constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation. (Source: RTCA GNSS Task Force Working Group 2: adapted from the ICAO FANS GNSS Technical Subgroup.)

Global Positioning System (GPS) — The satellite-based navigation system operated by the United States.

GLONASS — Global Navigation Satellite System (of the Russian Federation).

H_0 Hypothesis — The H_0 hypothesis assumes the situation where no faults are present in the range measurements (includes both the signal and the receiver measurements) used in the ground station to compute the differential corrections.

H_1 Hypothesis — The H_1 hypothesis assumes the situation when a fault is present in one or more range measurements and is caused by one of the reference receivers used in the ground station.

Height Above Touchdown (HAT) — Specifically, the height above the LTP/FTP. In using this term for airborne equipment specifications, care should be taken to define the point on the aircraft (e.g., GPS antenna, wheel height, or center of mass) that applies.

ICAO — International Civil Aviation Organization

ICD — Interface Control Document

ID — Identifier

IOD — GPS Issue of Data

ISO — International Standards Organization

LAAS — Local Area Augmentation System

Landing Threshold Point (LTP) — The LTP is a point at the designated center of the landing runway defined by latitude, longitude, ellipsoidal height, and orthometric height. The LTP is used in conjunction with the FPAP and the geometric center of the WGS-84 ellipsoid to define the geodesic plane of a precision final approach flight path to touchdown and rollout. The LTP is a surveyed reference point used to connect the approach flight path with the runway. The LTP is typically coincident with the designated runway threshold, but may be displaced from the threshold.

LSB — Least Significant Bit

Mask Angle — A fixed elevation angle referenced to the user's horizon below which satellites are ignored by the receiver software. Mask angles are used primarily in the analysis of GNSS performance, and are employed in some receiver designs. The mask angle is driven by the receiver antenna characteristics, the strength of the transmitted signal at low elevations, receiver sensitivity and acceptable low elevation errors.

MBI — Message Block Identifier

MSB — Most Significant Bit

Navigation — The means by which an aircraft is given guidance to travel from one known position to another known position. The process involves referencing the actual aircraft position to a desired course.

nmi — Nautical Mile

Non-Precision Approach — A standard instrument approach procedure in which no glideslope/glide path is provided. (Source: FAA document 7110.65G)

PCR — Pseudorange Correction Rate

PRC — Pseudorange Correction

Precision Approach — A standard instrument approach procedure in which a glideslope/glide path is provided. (Source: FAA document 7110.65G)

PRN — Pseudorandom Number

Pseudolite — A pseudolite (pseudo-satellite) is a ground-based GNSS augmentation that provides an additional navigation ranging signal which is at GNSS ranging source signal-in-space frequencies. The augmentation may include additionally differential GNSS corrections. (Adapted from the FANS GNSS Technical Subgroup.)

Pseudorange — The distance from the user to a ranging source plus an unknown user clock offset distance. With four ranging source signals it is possible to compute position and offset distance. If the user clock offset is known, three ranging source signals would suffice to compute a position.

Reference Receiver — A subsystem of the Ground Subsystem that is used to make pseudorange measurements and may contain more than one receiver.

RF — Radio Frequency

RFI — Radio Frequency Interference

RMS — Root Mean Squared

RSS — Root Sum Square

Satellite-Based Augmentation System (SBAS) — is a differential GNSS employing satellite transponders to broadcast differential corrections, integrity information and additional ranging signals usable over an extensive geographical area for the supported phases of operation.

sec — seconds

Selective Availability (SA) — A set of techniques for denying the full accuracy and selecting the level of positioning, velocity, and time accuracy of GPS available to users of the Standard Positioning Service (L1 frequency) signal.

SIS — Signal-in-Space

Standard Positioning Service (SPS) — The standard specified level of positioning, velocity and timing accuracy that is available, without qualifications or restrictions, to any user on a continuous worldwide basis.

TBD — To Be Determined

TCH — Threshold Crossing Height

TDMA — Time Division Multiple Access

TOW — Time of Week

UTC — Coordinated Universal Time

VDB — VHF Data Broadcast

WGS-84 — World Geodetic Survey – 1984

Wide Area Augmentation System (WAAS) — The SBAS operated by the U.S. FAA.

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