COVER SHEET TO AMENDMENT 86

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERONAUTICAL TELECOMMUNICATIONS

ANNEX 10
TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
RADIO NAVIGATION AIDS

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INTERNATIONAL CIVIL AVIATION ORGANIZATION

Checklist of Amendments to Annex 10, Volume I

	Effective date	*Date of applicability*
Sixth Edition (incorporates Amendments 1 to 81)	17 July 2006	23 November 2006
Amendment 82 (adopted by the Council on 26 February 2007)	16 July 2007	22 November 2007
Amendment 83 (adopted by the Council on 10 March 2008)	20 July 2008	20 November 2008
Amendment 84 (adopted by the Council on 6 March 2009)	20 July 2009	19 November 2009
Amendment 85 (adopted by the Council on 26 February 2010)	12 July 2010	18 November 2010
Amendment 86 (adopted by the Council on 4 March 2011) Replacement pages (iii), (iv), (xix), 3-67, APP B-76, APP B-82, APP B-83, APP B-86 to APP B-148, ATT C-2, ATT D-3, ATT D-5, ATT D-17 to ATT D-65	18 July 2011	17 November 2011

Transmittal note

Amendment 86

to the

International Standards and
Recommended Practices

AERONAUTICAL TELECOMMUNICATIONS

(Annex 10, Volume I, to the Convention on International Civil Aviation)

1. Insert the following replacement pages in Annex 10, Volume I (Sixth Edition) to incorporate Amendment 86 which becomes applicable on 17 November 2011:

a)	Pages (iii) and (iv)	— Table of Contents
b)	Page (xix)	— Foreword
c)	Page 3-67	— Chapter 3
d)	Pages APP B-76, APP B-82, APP B-83, APP B-86 to APP B-148	— Appendix B to Chapter 3
e)	Page ATT C-2	— Attachment C
f)	Pages ATT D-3, ATT D-5, ATT D-17 to ATT D-65	— Attachment D

2. Record the entry of this amendment on page (ii).

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ATTACHMENTS

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
85	Navigation Systems Panel (NSP)	a) improvement of the instrument landing system (ILS) localizer signal quality at aerodromes where building or terrain reflections cause interference of the reflected signal with the desired signal; b) extension of global navigation satellite system (GNSS) Category I approach operations; and c) evolution of the GLObal NAvigation Satellite System (GLONASS).	26 February 2010 12 July 2010 18 November 2010
86	Navigation Systems Panel (NSP)	Changes reflecting experience gained with initial implementation of the global navigation satellite system (GNSS) ground-based augmentation system (GBAS).	4 March 2011 18 July 2011 17 November 2011

* Did not affect any Standards or Recommended Practices.

3.7.3.5.2 *Functions*. GBAS shall perform the following functions:

a) provide locally relevant pseudo-range corrections;

b) provide GBAS-related data;

c) provide final approach segment data when supporting precision approach;

d) provide predicted ranging source availability data; and

e) provide integrity monitoring for GNSS ranging sources.

3.7.3.5.3 *Coverage*

3.7.3.5.3.1 *Category I precision approach and approach with vertical guidance.* The GBAS coverage to support each Category I precision approach or approach with vertical guidance shall be as follows, except where topographical features dictate and operational requirements permit:

a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out ±35 degrees either side of the final approach path to 28 km (15 NM) and ±10 degrees either side of the final approach path to 37 km (20 NM); and

b) vertically, within the lateral region, up to the greater of 7 degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. This coverage applies between 30 m (100 ft) and 3 000 m (10 000 ft) height above threshold (HAT).

Note.— LTP/FTP and GPIP are defined in Appendix B, 3.6.4.5.1.

3.7.3.5.3.1.1 **Recommendation.—** *For Category I precision approach, the data broadcast as specified in 3.7.3.5.4 should extend down to 3.7 m (12 ft) above the runway surface.*

3.7.3.5.3.1.2 **Recommendation.—** *The data broadcast should be omnidirectional when required to support the intended applications.*

Note.— Guidance material concerning coverage for Category I precision approach and APV is provided in Attachment D, 7.3.

3.7.3.5.3.2 *GBAS positioning service.* The GBAS positioning service area shall be that area where the data broadcast can be received and the positioning service meets the requirements of 3.7.2.4 and supports the corresponding approved operations.

Note.— Guidance material concerning the positioning service coverage is provided in Attachment D, 7.3.

3.7.3.5.4 *Data broadcast characteristics*

Note.— RF characteristics are specified in Appendix B, 3.6.2.

3.7.3.5.4.1 *Carrier frequency*. The data broadcast radio frequencies used shall be selected from the radio frequencies in the band 108 to 117.975 MHz. The lowest assignable frequency shall be 108.025 MHz and the highest assignable frequency shall be 117.950 MHz. The separation between assignable frequencies (channel spacing) shall be 25 kHz.

Note 1.— Guidance material on VOR/GBAS frequency assignments and geographical separation criteria is given in Attachment D, 7.2.1.

Note 2.— ILS/GBAS geographical separation criteria and geographical separation criteria for GBAS and VHF communication services operating in the 118 – 137 MHz band are under development. Until these criteria are defined and included in SARPs, it is intended that frequencies in the band 112.050 – 117.900 MHz will be used.

3.7.3.5.4.2 *Access technique*. A time division multiple access (TDMA) technique shall be used with a fixed frame structure. The data broadcast shall be assigned one to eight slots.

Note.— Two slots is the nominal assignment. Some GBAS facilities that use multiple VHF data broadcast (VDB) transmit antennas to improve VDB coverage may require assignment of more than two time slots. Guidance on the use of multiple antennas is given in Attachment D, 7.12.4; some GBAS broadcast stations in a GRAS may use one time slot.

3.7.3.5.4.3 *Modulation*. GBAS data shall be transmitted as 3-bit symbols, modulating the data broadcast carrier by D8PSK, at a rate of 10 500 symbols per second.

3.7.3.5.4.4 *Data broadcast RF field strength and polarization*

Note.— GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment. Relevant guidance material is provided in Attachment D, 7.1.

3.7.3.5.4.4.1 *GBAS/H*

3.7.3.5.4.4.1.1 A horizontally polarized signal shall be broadcast.

3.7.3.5.4.4.1.2 The effective radiated power (ERP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) and a maximum field strength of 0.350 volts per metre (–35 dBW/m^2) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and any VPOL components shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL users throughout the coverage volume.

3.7.3.5.4.4.2 *GBAS/E*

3.7.3.5.4.4.2.1 **Recommendation.—** *An elliptically polarized signal should be broadcast whenever practical.*

3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in 3.7.3.5.4.4.1.2, and the effective radiated power (ERP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m^2) and a maximum field strength of 0.221 volts per metre (–39 dBW/m^2) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and VPOL components, shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL and VPOL users throughout the coverage volume.

Note.— The minimum and maximum field strengths in 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 are consistent with a minimum receiver sensitivity of –87 dBm and minimum distance of 200 m (660 ft) from the transmitter antenna for a coverage range of 43 km (23 NM).

3.5.8.4.3.4 The receiver shall compute and apply horizontal and vertical protection levels as defined in 3.5.5.6. In this computation, s_{tropo} shall be:

$$\frac{1}{\sqrt{0{,}002+\text{sen}^2(\theta_i)}}\times 0.12 \text{ m}$$

where θ_i is the elevation angle of the i^{th} satellite.

In addition, σ_{air} shall satisfy the condition that a normal distribution with zero mean and standard deviation equal to σ_{air} bounds the error distribution for residual aircraft pseudo-range errors as follows:

$$\int_y^{\infty} f_n(x)dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0$$

where

$f_n(x)$ = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^{\infty} e^{-\frac{t^2}{2}}dt$$

Note.— The standard allowance for airborne multipath defined in 3.6.5.5.1 may be used to bound the multipath errors.

3.5.8.4.4 **Recommendation.—** *For departure, en-route, terminal, and non-precision approach operations, the receiver should use the broadcast ionospheric corrections, when available, and a tropospheric model with performance equal to that specified in 3.5.8.4.3.*

3.5.9 INTERFACE BETWEEN SBAS

Note.— Guidance material on the interface between different SBAS service providers is given in Attachment D, 6.3.

3.6 Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

Note.— In this section, except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

3.6.1 GENERAL

The GBAS shall consist of a ground subsystem and an aircraft subsystem. The GBAS ground subsystem shall provide data and corrections for the GNSS ranging signals over a digital VHF data broadcast to the aircraft subsystem. The GRAS ground subsystem shall consist of one or more GBAS ground subsystems.

Note.— Guidance material is provided in Attachment D, 7.1.

3.6.2 RF CHARACTERISTICS

3.6.2.1 *Carrier frequency stability*. The carrier frequency of the data broadcast shall be maintained within ±0.0002 per cent of the assigned frequency.

3.6.2.2 *Bit-to-phase-change encoding*. GBAS messages shall be assembled into symbols, each consisting of 3 consecutive message bits. The end of the message shall be padded by 1 or 2 fill bits if necessary to form the last 3-bit symbol of the message. Symbols shall be converted to D8PSK carrier phase shifts ($\Delta\phi_k$) in accordance with Table B-58.

Note.— The carrier phase for the k^{th} symbol (ϕ_k) is given by: $\phi_k = \phi_{k-1} + \Delta\phi_k$. The D8PSK signal may be produced as shown in Figure B-19 by combining two quadrature RF signals which are independently suppressed-carrier amplitude-modulated by base band filtered impulses. A positive increase in $\Delta\phi_k$ represents a counterclockwise rotation in the complex I-Q plane of Figure B-19.

3.6.2.3 *Modulation wave form and pulse shaping filters*. The output of differential phase encoder shall be 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;
ϕ_k = (as defined in 3.6.2.2);
t = time; and
T = the duration of each symbol = 1/10 500 second.

This pulse shaping filter shall have a nominal complex frequency response of a raised-cosine filter with α = 0.6. The time response, h(t), and frequency response, H(f), of the base band filters shall be as follows:

$$h(t)=\frac{\text{sen}\left(\frac{\pi t}{T}\right)\cos\left(\frac{\pi\alpha t}{T}\right)}{\frac{\pi t}{T}\left[1-\left(\frac{2\alpha t}{T}\right)^2\right]}$$

$$H(f)=\begin{cases} 1 & \text{for} \quad 0\le f<\frac{1-\alpha}{2T} \\ \frac{1-\text{sen}\left(\frac{\pi}{2\alpha}(2fT-1)\right)}{2} & \text{for} \quad \frac{1-\alpha}{2T}\le f\le\frac{1+\alpha}{2T} \\ 0 & \text{for} \quad f>\frac{1+\alpha}{2T} \end{cases}$$

The output s(t) of the pulse shaping filter shall modulate the carrier.

3.6.2.4 *Error vector magnitude.* The error vector magnitude of the transmitted signal shall be less than 6.5 per cent root-mean-square (1 sigma).

3.6.2.5 *RF data rate*. The symbol rate shall be 10 500 symbols per second ±0.005 per cent, resulting in a nominal bit rate of 31 500 bits per second.

Table B-61. Format of a GBAS message block

Message block	Bits
Message block header	48
Message	up to 1 696
CRC	32

Table B-62. Format of message block header

Data field	Bits
Message block identifier	8
GBAS ID	24
Message type identifier	8
Message length	8

3.6.3.3.6 *Bit scrambling*

3.6.3.3.6.1 The output of a pseudo-noise scrambler with a 15-stage generator register shall be exclusive OR'ed with the burst data starting with the SSID and ending with the application FEC. Bit scrambling of the 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 and their values have no impact on the system.

3.6.3.3.6.2 The polynomial for the register taps of the scrambler shall be $1 + x + x^{15}$. The register content shall be rotated at the rate of one shift per bit. The initial status of the register, prior to the first SSID bit of each burst, shall be "1101 0010 1011 001", with the leftmost bit in the first stage of the register. The first output bit of the scrambler shall be sampled prior to the first register shift.

Note.— A diagram of the bit scrambler is given in Attachment D, 7.4.

3.6.3.4 *Message block format*. The message blocks shall consist of a message block header, a message and a 32-bit CRC. Table B-61 shows the construction of the message block. All signed parameters shall be two's complement numbers and all unsigned parameters shall be unsigned fixed point numbers. The scaling of the data shall be as shown in the message tables in 3.6.6. All data fields in the message block shall be transmitted in the order specified in the message tables, with the LSB of each field transmitted first.

Note.— All binary representations reading left to right are MSB to LSB.

3.6.3.4.1 *Message block header*. The message block header shall consist of a message block identifier, a GBAS identifier (ID), a message type identifier and a message length, as shown in Table B-62.

Message block identifier: the 8-bit identifier for the operating mode of the GBAS message block.

Coding: 1010 1010 = normal GBAS message
1111 1111 = test GBAS message
All other values are reserved.

GBAS ID: the four-character GBAS identification to differentiate between GBAS ground subsystems.

Coding: Each character is coded using bits b_1 through b_6 of its International Alphabet No. 5 (IA-5) representation. For each character, bit b_1 is transmitted first and six bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character GBAS ID, the rightmost (first transmitted) character shall be IA-5 "space".

Note.— The GBAS ID is normally identical to the location indicator at the nearest airport. Assignment of GBAS IDs will be coordinated as appropriate to avoid conflicts.

Message type identifier: the numeric label identifying the content of the message (Table B-63).

Message length: the length of the message in 8-bit bytes including the 6-byte message block header, the message and the 4-byte message CRC code.

3.6.3.4.2 *Cyclic redundancy check (CRC).* The GBAS message CRC shall be calculated in accordance with 3.9.

3.6.3.4.2.1 The length of the CRC code shall be k = 32 bits.

3.6.3.4.2.2 The CRC generator polynomial shall be:

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

3.6.3.4.2.3 The CRC information field, M(x), shall be:

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

3.6.3.4.2.4 M(x) shall be formed from the 48-bit GBAS message block header and all bits of the variable-length message, excluding the CRC. Bits shall be 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.

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

3.6.4 DATA CONTENT

3.6.4.1 *Message types*. The message types that can be transmitted by GBAS shall be as in Table B-63.

3.6.4.2 *TYPE 1 MESSAGE — PSEUDO-RANGE CORRECTIONS*

3.6.4.2.1 The Type 1 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70). The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter, satellite ephemeris CRC and satellite availability information); and

c) satellite data measurement blocks.

Note.— Transmission of the low-frequency data for SBAS ranging sources is optional.

3.6.4.2.2 Each Type 1 message shall include ephemeris decorrelation parameter, ephemeris CRC and source availability duration parameters for one satellite ranging source. The ephemeris decorrelation parameter, ephemeris CRC and source availability duration shall apply to the first ranging source in the message.

3.6.4.2.3 Pseudo-range correction parameters shall be as follows:

Modified Z-count: the indication of the time of applicability for all the parameters in the message.

Coding: the modified Z-count resets on the hour (xx:00), 20 minutes past the hour (xx:20) and 40 minutes past the hour (xx:40) referenced to GPS time.

Additional message flag: an identification of whether the set of 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.

Coding: 0 = All measurement blocks for a particular measurement type are contained in one Type 1 message.
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 = Spare
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.— When a linked pair of Type 1 messages is used for a particular measurement type, the number of measurements and low-frequency data are computed separately for each of the two individual messages.

Number of measurements: the number of measurement blocks in the message.

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

Table B-63. GBAS VHF data broadcast messages

Message type identifier	Message name
0	Spare
1	Pseudo-range corrections
2	GBAS-related data
3	Null message
4	Final approach segment (FAS) data
5	Predicted ranging source availability
6	Reserved
7	Reserved for national applications
8	Reserved for test applications
9 to 100	Spare
101	GRAS pseudo-range corrections
102 to 255	Spare

Note.— See 3.6.6 for message formats.

Coding: 0 = C/A or CSA code L1
1 = reserved
2 = reserved
3 = reserved
4 to 7 = spare

Ephemeris decorrelation parameter (P): a parameter that characterizes the impact of residual ephemeris errors due to decorrelation for the first measurement block in the message.

For a SBAS geostationary satellite, the ephemeris decorrelation parameter, if transmitted, shall be coded as all zeros.

For GBAS ground subsystems that do not broadcast the additional data block 1 in the Type 2 message, the ephemeris decorrelation parameter shall be coded as all zeros.

Ephemeris CRC: the CRC computed with the ephemeris data used to determine corrections for the first measurement block in the message. The ephemeris CRC for core satellite constellation(s) ranging sources shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 16 bits. The CRC generator polynomial shall be:

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

The CRC information field, M(x), for a given satellite shall be:

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

For a GPS satellite, M(x) shall be of length n = 576 bits. M(x) for a GPS satellite shall be calculated using the first 24 bits from each of words 3 to S10 of subframes 1, 2 and 3 of the data transmission from that satellite, ANDed with the GPS satellite ephemeris mask of Table B-64. M(x) shall be arranged in the order that bytes are transmitted by the GPS satellite, but with each byte ordered LSB first, such that m_1 corresponds to bit 68 of subframe 1, and m_{576} corresponds to bit 287 of subframe 3.

Note.— M(x) for a GPS satellite does not include word 1 (TLM) or word 2 (HOW), which start each subframe, or the 6 parity bits at the end of each word.

For a GLONASS satellite, M(x) shall be of length n = 340 bits. M(x) for a GLONASS satellite shall be calculated using strings 1, 2, 3 and 4 of the data transmission from that satellite, ANDed with the GLONASS satellite ephemeris mask of Table B-65. Bits shall be arranged in transmission order such that m_1 corresponds to bit 85 of string 1, and m_{340} corresponds to bit 1 of string 4.

For a SBAS geostationary satellite, the ephemeris CRC, if transmitted shall be coded as all zeros.

The CRC shall be transmitted in the order r_9, r_{10}, r_{11}...., r_{16}, r_1, r_2, r_3...r_8, where r_i is the i^{th} coefficient of the remainder R(x) as defined in 3.9**.**

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 = The duration is greater than or equal to 2 540 seconds.
1111 1111 = Prediction of source availability duration is not provided by this ground subsystem.

3.6.4.2.4 The measurement block parameters shall be as follows:

Ranging source ID: the identity of the ranging source to which subsequent measurement block data are applicable.

Table B-64. GPS satellite ephemeris mask

Subframe 1:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	0000 0000	0000 0000	0000 0011	Word 4	0000 0000	0000 0000	0000 0000
Word 5	0000 0000	0000 0000	0000 0000	Word 6	0000 0000	0000 0000	0000 0000
Word 7	0000 0000	0000 0000	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	1111 1100
Subframe 2:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	1111 1111	1111 1111	1111 1111	Word 4	1111 1111	1111 1111	1111 1111
Word 5	1111 1111	1111 1111	1111 1111	Word 6	1111 1111	1111 1111	1111 1111
Word 7	1111 1111	1111 1111	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	0000 0000
Subframe 3:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	1111 1111	1111 1111	1111 1111	Word 4	1111 1111	1111 1111	1111 1111
Word 5	1111 1111	1111 1111	1111 1111	Word 6	1111 1111	1111 1111	1111 1111
Word 7	1111 1111	1111 1111	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	1111 1100

Table B-65. GLONASS satellite ephemeris mask

String 1: 0 0000 0000 0000 0000 0000 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 0000 0000 String 2: 0 0000 0000 0000 0000 0000 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 0000 0000 String 3: 0 0000 0111 1111 1111 0000 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 0000 0000 String 4: 0 0000 1111 1111 1111 1111 1111 1100 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000

Coding:
- 1 to 36 = GPS satellite IDs (PRN)
- 37 = reserved
- 38 to 61 = GLONASS satellite IDs (slot number plus 37)
- 62 to 119 = spare
- 120 to 138 = SBAS satellite IDs (PRN)
- 139 to 255 = spare

Issue of data (IOD): The issue of data associated with the ephemeris data used to determine pseudo-range and range rate corrections.

Coding: for GPS, IOD = GPS IODE parameter (3.1.1.3.2.2)
for GLONASS, IOD = GLONASS "t_b" parameter (see 3.2.1.3.1)
for SBAS, IOD = 1111 1111

Note.— For GLONASS insert 0 in the MSB of the IOD.

Pseudo-range correction (PRC): the correction to the ranging source pseudo-range.

Range rate correction (RRC): the rate of change of the pseudo-range correction.

σ_{pr_gnd}: the standard deviation of a normal distribution associated with the signal-in-space contribution of the pseudo-range error at the GBAS reference point (3.6.5.5.1, 3.6.5.5.2 and 3.6.7.2.2.4).

Coding: 1111 1111 = Ranging source correction invalid.

B_1 through B_4: are the integrity parameters associated with the pseudo-range corrections provided in the same measurement block. For the i^{th} ranging source these parameters correspond to $B_{i,1}$ through $B_{i,4}$ (3.6.5.5.1.2, 3.6.5.5.2.2 and 3.6.7.2.2.4). The indices "1-4" correspond to the same physical reference receiver for every frame transmitted from a given ground subsystem during continuous operation.

Coding: 1000 0000 = Reference receiver was not used to compute the pseudo-range correction.

Note.— Some airborne receivers may expect a static correspondence of the reference receivers to the indices for short service interruptions. However, the B-value indices may be reassigned after the ground subsystem has been out of service for an extended period of time, such as for maintenance.

3.6.4.3 *Type 2 message — GBAS-related data.* Type 2 message shall identify the location of the GBAS reference point at which the corrections provided by the GBAS apply and shall give other GBAS-related data (Table B-71). GBAS-related data parameters shall be as follows:

Note.— Additional data blocks may be included in the Type 2 message. Additional data block 1 and additional data block 2 are defined. In the future, other additional data blocks may be defined. Data blocks 2 through 255 are variable length and may be appended to the message after additional data block 1 in any order.

GBAS reference receivers: the number of GNSS reference receivers installed in this GBAS ground subsystem.

Coding: 0 = GBAS installed with 2 reference receivers
1 = GBAS installed with 3 reference receivers
2 = GBAS installed with 4 reference receivers
3 = The number of GNSS reference receivers installed in this GBAS ground subsystem is not applicable

Ground accuracy designator letter: the letter designator indicating the minimum signal-in-space accuracy performance provided by GBAS (3.6.7.1.1).

Coding: 0 = accuracy designation A
1 = accuracy designation B
2 = accuracy designation C
3 = spare

GBAS continuity/integrity designator (GCID): numeric designator indicating the operational status of the GBAS.

Coding: 0 = spare
1 = GCID 1
2 = GCID 2
3 = GCID 3
4 = GCID 4
5 = spare
6 = spare
7 = unhealthy

Note 1.— The values of GCID 2, 3 and 4 are specified in order to ensure compatibility of equipment with future GBAS.

Note 2.— The value of GCID 7 indicates that a precision approach or APV cannot be initiated.

Local magnetic variation: the published magnetic variation at the GBAS reference point.

Coding: Positive value denotes east variation (clockwise from true north), Negative value denotes west variation (counter-clockwise from true north)
100 0000 0000 = Precision approach procedures supported by this GBAS are published based on true bearing.

Note.— Local magnetic variation is chosen to be consistent with procedure design and is updated during magnetic epoch years.

$\sigma_{vert\_iono\_gradient}$: the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation (3.6.5.4).

Refractivity index (N_r): the nominal tropospheric refractivity index used to calibrate the tropospheric correction associated with the GBAS ground subsystem (3.6.5.3).

Coding: This field is coded as two's complement number with an offset of +400. A value of zero in this field indicates a refractivity index of 400.

Scale height (h_0): a scale factor used to calibrate the tropospheric correction and residual tropospheric uncertainty associated with the GBAS ground subsystem (3.6.5.3).

Refractivity uncertainty (σ_n): the standard deviation of a normal distribution associated with the residual tropospheric uncertainty (3.6.5.3).

Latitude: the latitude of the GBAS reference point defined in arc seconds.

Coding: Positive value denotes north latitude.
Negative value denotes south latitude.

Longitude: the longitude of the GBAS reference point defined in arc seconds.

Coding: Positive value denotes east longitude.
Negative value denotes west longitude.

Reference point height: the height of the GBAS reference point above the WGS-84 ellipsoid.

3.6.4.3.1 *Additional data block 1 parameters*. Additional data block 1 parameters shall be as follows:

REFERENCE STATION DATA SELECTOR (RSDS): the numerical identifier that is used to select the GBAS ground subsystem.

Note.— The RSDS is different from every other RSDS and every reference path data selector (RPDS) broadcast on the same frequency by every GBAS ground subsystem within the broadcast region.

Coding: 1111 1111 = GBAS positioning service is not provided

MAXIMUM USE DISTANCE (D_{max}): the maximum distance (slant range) from the GBAS reference point for which the integrity is assured.

Note.— This parameter does not indicate a distance within which VHF data broadcast field strength requirements are met.

Coding: 0 = No distance limitation

GPS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e\_POS,GPS}$): 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 subsystems that do not broadcast corrections for GPS ranging sources or that do not provide the GBAS positioning service, this parameter shall be coded as all zeros.

GPS EPHEMERIS MISSED DETECTION PARAMETER, Category I Precision Approach and APV ($K_{md\_e,GPS}$): the multiplier for computation of the ephemeris error position bound for Category I precision approach and APV derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e,\_POS,GLONASS}$): 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 subsystems that do not broadcast corrections for GLONASS ranging sources or that do not provide positioning service, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, Category I Precision Approach and APV ($K_{md\_e\_,GLONASS}$): the multiplier for computation of the ephemeris error position bound for Category I precision approach and APV derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources, this parameter shall be coded as all zeros.

3.6.4.3.2 *Additional data blocks*. For additional data blocks other than additional data block 1, the parameters for each data block shall be as follows:

ADDITIONAL DATA BLOCK LENGTH: the number of bytes in the additional data block, including the additional data block length and additional data block number fields.

ADDITIONAL DATA BLOCK NUMBER: the numerical identifier of the type of additional data block.

Coding: 0 to 1 = reserved
2 = additional data block 2, GRAS broadcast stations
3 = reserved for future services supporting Category II/III operations
4 = additional data block 4, VDB authentication parameters
5 to 255 = spare

ADDITIONAL DATA PARAMETERS: the set of data defined in accordance with the additional data block number.

3.6.4.3.2.1 *GRAS broadcast stations*

Parameters for additional data block 2 shall include data for one or more broadcast stations as follows (Table B-65A):

CHANNEL NUMBER: the channel number, as defined in 3.6.5.7, associated with a GBAS broadcast station.

Note.— The channel number in this field refers to a frequency and an RSDS.

Δ*LATITUDE*: the difference of latitude of a GBAS broadcast station, measured from the latitude provided in the latitude parameter of Type 2 message.

Coding: Positive value denotes that the GBAS broadcast station is north of the GBAS reference point.
Negative value denotes that the GBAS broadcast station is south of the GBAS reference point.

Δ*LONGITUDE*: the difference of longitude of a GBAS broadcast station, measured from the longitude provided in the longitude parameter of Type 2 message.

Coding: Positive value denotes that the GBAS broadcast station is east of the GBAS reference point.
Negative value denotes that the GBAS broadcast station is west of the GBAS reference point.

Note.— Guidance material concerning additional data block 2 is provided in Attachment D, 7.17.

Table B-65A. GRAS broadcast station data

Data content	Bits used	Range of values	Resolution
Channel number	16	20001 to 39999	1
ΔLatitude	8	±25.4°	0.2°
ΔLongitude	8	±25.4°	0.2°

3.6.4.3.2.2 *VDB authentication parameters*

Additional data block 4 includes information needed to support VDB authentication protocols (Table B-65B).

Slot group definition: This 8-bit field indicates which of the 8 slots (A-H) are assigned for use by the ground station. The field is transmitted LSB first. The LSB corresponds to slot A, the next bit to slot B, and so on. A “1” in the bit position indicates the slot is assigned to the ground station. A “0” indicates the slot is not assigned to the ground station.

Table B-65B. VDB authentication parameters

Data content	Bits used	Range of values	Resolution
Slot group definition	8	—	—

3.6.4.4 *TYPE 3 MESSAGE — NULL MESSAGE*

3.6.4.4.1 The Type 3 message is a variable length “null message” which is intended to be used by ground subsystems that support the authentication protocols (see section 3.6.7.4).

3.6.4.4.2 The parameters for the Type 3 message shall be as follows:

Filler: a sequence of bits alternating between “1” and “0” with a length in bytes that is 10 less than the value in the message length field in the message header.

3.6.4.5 *Type 4 message — Final approach segment (FAS).* Type 4 message shall contain one or more sets of FAS data, each defining a single precision approach (Table B-72). Each Type 4 message data set shall include the following:

Data set length: the number of bytes in the data set. The data set includes the data set length field and the associated FAS data block, FAS vertical alert limit (FASVAL)/approach status and FAS lateral alert limit (FASLAL)/approach status fields.

FAS data block: the set of parameters to identify a single precision approach or APV and define its associated approach path.

Coding: See 3.6.4.5.1 and Table B-66.

Note.— Guidance material for FAS path definition is contained in Attachment D, 7.11.

FASVAL/approach status: the value of the parameter FASVAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use vertical deviations.

Note.— The range and resolution of values for FASVAL depend upon the approach performance designator in the associated FAS data block.

FASLAL/approach status: the value of the parameter FASLAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use approach.

3.6.4.5.1 *FAS data block.* The FAS data block shall contain the parameters that define a single precision approach or APV. 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 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. FAS data block parameters shall be as follows:

Operation type: straight-in approach procedure or other operation types.

Coding: 0 = straight-in approach procedure
1 to 15 = spare

SBAS service provider ID: indicates the service provider associated with this FAS data block.

Coding: See Table B-27.
14 = FAS data block is to be used with GBAS only.
15 = FAS data block can be used with any SBAS service provider.

Note.— This parameter is not used for approaches conducted using GBAS or GRAS pseudo-range corrections.

Table B-66. Final approach segment (FAS) data block

Data content	Bits used	Range of values	Resolution
Operation type	4	0 to 15	1
SBAS provider ID	4	0 to 15	1
Airport ID	32	—	—
Runway number	6	0 to 36	1
Runway letter	2	—	—
Approach performance designator	3	0 to 7	1
Route indicator	5	—	—
Reference path data selector	8	0 to 48	1
Reference path identifier	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 to 6 041.5 m	0.1 m
ΔFPAP latitude	24	±1.0°	0.0005 arcsec
ΔFPAP longitude	24	±1.0°	0.0005 arcsec
Approach TCH (Note 2)	15	0 to 1 638.35 m or 0 to 3 276.7 ft	0.05 m or 0.1 ft
Approach TCH units selector	1	—	—
GPA	16	0 to 90.0°	0.01°
Course width (Note 1)	8	80 to 143.75 m	0.25 m
ΔLength offset	8	0 to 2 032 m	8 m
Final approach segment CRC	32	—	—

Note 1.— When the runway number is set to 0, then the course width field is ignored and the course width is 38 metres.

Note 2.— Information can be provided in either feet or metres as indicated by the approach TCH unit selector.

Airport ID: the three- or four-letter designator used to designate an airport.

Coding: Each character is coded using the lower 6 bits of its IA-5 representation. For each character, b_i is transmitted first, and 2 zero bits are appended after b_6, so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 “space” are used. The rightmost character is transmitted first. For a three-character airport ID, the rightmost (first transmitted) character shall be IA-5 “space”.

Runway number: the approach runway number.

Coding: 0 = heliport
1 to 36 = runway number

Runway letter: the one-letter designator used, as necessary, to differentiate between parallel runways.

Coding: 0 = no letter
1 = R (right)
2 = C (centre)
3 = L (left)

Approach performance designator: the general information about the approach design.

Coding: 0 = APV
1 = Category I
2 = reserved for Category II
3 = reserved for Category III
4 to 7 = spare

Note.— Some airborne equipment designed for Category I performance is insensitive to the value of the APD. It is intended that airborne equipment designed for Category I performance accepts APD values of at least 1-4 as valid to accommodate future extensions to higher performance types using the same FAS data block.

Route indicator: the one-letter identifier used to differentiate between multiple approaches to the same runway end.

Coding: The letter is coded using bits b_1 through b_5 of its IA-5 representation. Bit b_1 is transmitted first. Only upper case letters, excluding "I" and "O", or IA-5 "space" are used.

Reference path data selector (RPDS): the numeric identifier that is used to select the FAS data block (desired approach).

Note.— The RPDS for a given FAS data block is different from every other RPDS and every reference station data selector (RSDS) broadcast on the same frequency by every GBAS within the broadcast region.

Reference path identifier (RPI): the three or four alphanumeric characters used to uniquely designate the reference path.

Coding: Each character is coded using bits b_1 through b_6 of its IA-5 representation. For each character, b_1 is transmitted first, and 2 zero bits are appended after b_6 so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character reference path identifier, the rightmost (first transmitted) character shall be IA-5 "space".

Note.— The LTP/FTP is a point over which the FAS path passes at a relative height specified by the TCH. LTP is normally located at the intersection of the runway centreline and the threshold.

LTP/FTP latitude: the latitude of the LTP/FTP point in arc seconds.

Coding: Positive value denotes north latitude.
Negative value denotes south latitude.

LTP/FTP longitude: the longitude of the LTP/FTP point in arc seconds.

Coding: Positive value denotes east longitude.
Negative value denotes west longitude.

LTP/FTP height: the height of the LTP/FTP above the WGS-84 ellipsoid.

Coding: This field is coded as an unsigned fixed-point number with an offset of –512 metres. A value of zero in this field places the LTP/FTP 512 metres below the earth ellipsoid.

Note.— The FPAP is a point at the same height as the LTP/FTP that is used to define the alignment of the approach. The origin of angular deviations in the lateral direction is defined to be 305 metres (1 000 ft) beyond the FPAP along the lateral FAS path. For an approach aligned with the runway, the FPAP is at or beyond the stop end of the runway.

ΔFPAP latitude: the difference of latitude of the runway FPAP from the LTP/FTP in arc seconds.

Coding: Positive value denotes the FPAP latitude north of LTP/FTP latitude.
Negative value denotes the FPAP latitude south of the LTP/FTP latitude.

ΔFPAP longitude: the difference of longitude of the runway FPAP from the LTP/FTP in arc seconds.

Coding: Positive value indicates the FPAP longitude east of LTP/FTP longitude.
Negative value indicates the FPAP longitude west of LTP/FTP longitude.

Approach TCH: the height of the FAS path above the LTP/FTP defined in either feet or metres as indicated by the TCH units selector.

Approach TCH units selector: the units used to describe the TCH.

Coding: 0 = feet
1 = metres

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

Course width: the lateral displacement from the path defined by the FAS at the LTP/FTP at which full-scale deflection of a course deviation indicator is attained.

Coding: This field is coded as an unsigned fixed-point number with an offset of 80 metres. A value of zero in this field indicates a course width of 80 metres at the LTP/FTP.

ΔLength offset: the distance from the stop end of the runway to the FPAP.

Coding: 1111 1111 = not provided

Final approach segment CRC: the 32-bit CRC appended to the end of each FAS data block in order to ensure approach data integrity. The 32-bit final approach segment CRC shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 32 bits.

The CRC generator polynomial shall be:

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

The CRC information field, M(x), shall be:

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

M(x) shall be formed from all bits of the associated FAS data block, excluding the CRC. Bits shall be 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 shall be ordered such that r_1 is the LSB and r_{32} is the MSB.

3.6.4.6 *Type 5 message — predicted ranging source availability.* When used, the Type 5 message shall contain rising and setting information for the currently visible or soon to be visible ranging sources. Predicted ranging source availability parameters shall be as follows:

Modified Z-count: indicates the time of applicability of the parameters in this message.

Coding: Same as modified Z-count field in Type 1 message (3.6.4.2).

Number of impacted sources: the number of sources for which duration information applicable to all approaches is provided.

Coding: 0 = Only specified obstructed approaches have limitations.
1 to 31 = The number of ranging sources impacted.

Ranging source ID: as for Type 1 message (3.6.4.2).

Source availability sense: indicates whether the ranging source will become available or cease to be available.

Coding: 0 = Differential corrections will soon cease to be provided for the associated ranging source.
1 = Differential corrections will soon start to be provided for the associated ranging source.

Source availability duration: the predicted minimum ranging source availability duration relative to the modified Z-count.

Coding: 111 1111 = The duration is greater than or equal to 1 270 seconds.

Number of obstructed approaches: the number of approaches for which the corrections will be reduced due to approach unique constellation masking.

Reference path data selector: an indication of the FAS data block to which the source availability data applies (3.6.4.5.1).

Number of impacted sources for this approach: the number of sources for which duration information applicable only to this approach is provided.

3.6.4.7 *TYPE 6 MESSAGE*

Note.— Type 6 message is reserved for future use to provide the information required for Category II/III precision approaches.

3.6.4.8 *TYPE 7 MESSAGE*

Note.— Type 7 message is reserved for national applications.

3.6.4.9 *TYPE 8 MESSAGE*

Note.— Type 8 message is reserved for local and regional test applications.

3.6.4.10 *TYPE 101 MESSAGE — GRAS PSEUDO-RANGE CORRECTIONS*

3.6.4.10.1 The Type 101 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70A). The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter, satellite ephemeris CRC and satellite availability information); and

c) satellite data measurement blocks.

3.6.4.10.2 Each Type 101 message shall include ephemeris decorrelation parameter, ephemeris CRC and source availability duration parameters for one satellite ranging source. The ephemeris decorrelation parameter, ephemeris CRC and source availability duration shall apply to the first ranging source in the message.

3.6.4.10.3 Pseudo-range correction parameters shall be as follows:

Modified Z-count: as defined in 3.6.4.2.3.

Additional message flag: as defined in 3.6.4.2.3 except applicable to Type 101 messages.

Number of measurements: as defined in 3.6.4.2.3.

Measurement type: as defined in 3.6.4.2.3.

Ephemeris decorrelation parameter (P): as defined in 3.6.4.2.3.

Ephemeris CRC: as defined in 3.6.4.2.3.

Source availability duration: as defined in 3.6.4.2.3.

Number of B parameters: an indication of whether the B parameters are included in the measurement block for each ranging source.

Coding: 0 = B parameters are not included
1 = 4 B parameters per measurement block

3.6.4.10.4 The measurement block parameters shall be as follows:

Ranging source ID: as defined in 3.6.4.2.4.

Issue of data (IOD): as defined in 3.6.4.2.4.

Pseudo-range correction (PRC): as defined in 3.6.4.2.4.

Range rate correction (RRC): as defined in 3.6.4.2.4.

σ_{pr_gnd}: as defined in 3.6.4.2.4, with the exception of the range of values and resolution.

B1 through B4: as defined in 3.6.4.2.4.

Note.— Inclusion of the B parameters in the measurement block is optional for Type 101 messages.

3.6.5 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.

3.6.5.1 *Measured and carrier smoothed pseudo-range.* The broadcast correction is applicable to carrier smoothed code pseudo-range measurements that have not had the satellite broadcast troposphere and ionosphere corrections applied to them. The carrier smoothing is defined by the following filter:

$$P_{CSCn} = \alpha P + (1 - \alpha)\left(P_{CSC_{n-1}} + \frac{\lambda}{2\pi}(\phi_n - \phi_{n-1})\right)$$

where

P_{CSCn} = the smoothed pseudo-range;
P_{CSCn-1} = the previous smoothed pseudo-range;
P = the raw pseudo-range measurement where the raw pseudo-range measurements are obtained from a carrier driven code loop, first order or higher and with a one-sided noise bandwidth greater than or equal to 0.125 Hz;
λ = the L1 wavelength;
ϕ_n = the carrier phase;
ϕ_{n-1} = the previous carrier phase; and
α = the filter weighting function equal to the sample interval divided by the time constant of 100 seconds, except as specified in 3.6.8.3.5.1 for airborne equipment.

3.6.5.2 *Corrected pseudo-range.* The corrected pseudo-range for a given satellite at time *t* is:

$$PR_{corrected} = P_{CSC} + PRC + RRC \times (t - \text{tz-count}) + TC + c \times (\Delta t_{sv})_{L1}$$

where

P_{CSC} = the smoothed pseudo-range (defined in 3.6.5.1);
PRC = the pseudo-range correction (defined in 3.6.4.2);
RRC = the pseudo-range correction rate (defined in 3.6.4.2);
t = the current time;
tz-count = the time of applicability derived from the modified Z-count (defined in 3.6.4.2);
TC = the tropospheric correction (defined in 3.6.5.3); and
c and $(\Delta t_{sv})_{L1}$ are as defined in 3.1.2.2 for GPS satellites.

3.6.5.3 *TROPOSPHERIC DELAY*

3.6.5.3.1 The tropospheric correction for a given satellite is:

$$TC = N_r h_0 \frac{10^{-6}}{\sqrt{0.002 + \text{sen}^2(El_i)}}(1 - e^{-\Delta h/h_0})$$

where

N_r = refractivity index from the Type 2 message (3.6.4.3);
Δh = height of the aircraft above the GBAS reference point;
El_i = elevation angle of the i^{th} satellite; and
h_0 = troposphere scale height from the Type 2 message.

3.6.5.3.2 The residual tropospheric uncertainty is:

$$\sigma_{tropo} = \sigma_n h_0 \frac{10^{-6}}{\sqrt{0.002 + \text{sen}^2(El_i)}}(1 - e^{-\Delta h/h_0})$$

where σ_n = the refractivity uncertainty from the Type 2 message (3.6.4.3).

3.6.5.4 *Residual ionospheric uncertainty.* The residual ionospheric uncertainty for a given satellite 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 a given satellite (3.5.5.5.2);
$\sigma_{vert\_iono\_gradient}$ = (as defined in 3.6.4.3);
x_{air} = the distance (slant range) in metres between current aircraft location and the GBAS reference point indicated in the Type 2 message;
τ = 100 seconds (time constant used in 3.6.5.1); and
v_{air} = the aircraft horizontal approach velocity (metres per second).

3.6.5.5 *PROTECTION LEVELS*

3.6.5.5.1 *Category I precision approach and APV.* The signal-in-space vertical and lateral protection levels (VPL and LPL) are upper confidence bounds on the error in the position relative to the GBAS reference point defined as:

$$VPL = MAX\{VPL_{HO}, VPL_{H1}\}$$

$$LPL = MAX\{LPL_{HO}, LPL_{H1}\}$$

3.6.5.5.1.1 *Normal measurement conditions*

3.6.5.5.1.1.1 The vertical protection level (VPL_{H0}) and lateral protection level (LPL_{H0}), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$VPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where

K_{ffmd} = the multiplier derived from the probability of fault-free missed detection;
s_vert_i = $s_{v,i} + s_{x,i} \times \tan(GPA)$;
s_lat_i = $s_{y,i}$;
$s_{x,i}$ = the partial derivative of position error in the x-direction with respect to pseudo-range error on the i^{th} satellite;
$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the i^{th} satellite;
$s_{v,i}$ = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the i^{th} satellite;
GPA = the glidepath angle for the final approach path (3.6.4.5.1);
N = the number of ranging sources used in the position solution; and
i = the ranging source index for ranging sources used in the position solution.

Note.— The coordinate reference frame is defined such that x is along track positive forward, y is crosstrack positive left in the local level tangent plane and v is the positive up and orthogonal to x and y.

3.6.5.5.1.1.2 For a general-least-squares position solution, the projection matrix S is defined as:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \cdots & S_{x,N} \\ S_{y,1} & S_{y,2} & \cdots & S_{y,N} \\ S_{v,1} & S_{v,2} & \cdots & S_{v,N} \\ S_{t,1} & S_{t,2} & \cdots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

G_i = [–cos El_i cos Az_i –cos El_i sin Az_i –sin El_i 1] = i^{th} row of G; and

$$W = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_N^2 \end{bmatrix}^{-1}$$

where $\sigma^2_i = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i}$;

where

$\sigma_{pr\_gnd,i}$ = σ_{pr_gnd} for the i^{th} ranging source (3.6.4.2);
$\sigma_{tropo,i}$ = the residual tropospheric uncertainty for the i^{th} ranging source (3.6.5.3);
$\sigma_{iono,i}$ = the residual ionospheric delay (due to spatial decorrelation) uncertainty for the i^{th} ranging source (3.6.5.4); and
$\sigma_{pr\_air,i}$ = $\sqrt{\sigma^2_{receiver}(El_i) + \sigma^2_{multipath}(El_i)}$, the standard deviation of the aircraft contribution to the corrected pseudo-range error for the i^{th} ranging source. The total aircraft contribution includes the receiver contribution (3.6.8.2.1) and a standard allowance for airframe multipath;

where

$\sigma_{multipath}(El_i)$ = $0.13 + 0.53e^{-El_i/10\,deg}$, the standard model for the contribution of airframe multipath (in metres);
El_i = the elevation angle for the i^{th} ranging source (in degrees); and
Az_i = the azimuth for the i^{th} ranging source taken counterclockwise for the x axis (in degrees).

Note.— To improve readability, the subscript i *was omitted from the projection matrix's equation.*

3.6.5.5.1.2 *Faulted measurement conditions.* When the Type 101 message is broadcast without B parameter blocks, the values for VPL_{H1} and LPL_{H1} are defined as zero. Otherwise, the vertical protection level (VPL_{H1}) and lateral protection level (LPL_{H1}), assuming that a latent fault exists in one, and only one reference receiver, are:

$$VPL_{H1} = \max [VPL_j]$$

$$LPL_{H1} = \max [LPL_j]$$

where VPL_j and LPL_j for j = 1 to 4 are

VPL_j = $|B\_vert_j| + K_{md}\,\sigma_{vert,H1}$ and
LPL_j = $|B\_lat_j| + K_{md}\,\sigma_{lat,H1}$

and

B_vert_j = $\sum_{i=1}^{N}(s\_vert_i \times B_{i,j})$;

B_lat_j = $\sum_{i=1}^{N}(s\_lat_i \times B_{i,j})$;

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the j^{th} reference receiver measurement for the i^{th} ranging source;

K_{md} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted;

$\sigma^2_{vert,H1}$ = $\sum_{i=1}^{N}(s\_vert_i^2 \times \sigma\_H1_i^2)$;

$\sigma^2_{lat,H1}$ = $\sum_{i=1}^{N}(s\_lat_i^2 \times \sigma\_H1_i^2)$;

$\sigma\_H1^2_i$ = $\left(\frac{M_i}{U_i}\right)\sigma^2_{pr\_gnd,i} + \sigma^2_{pr\_air,i} + \sigma^2_{tropo,i} + \sigma^2_{iono,i}$;

M_i = the number of reference receivers used to compute the pseudo-range corrections for the i^{th} ranging source (indicated by the B values); and

U_i = the number of reference receivers used to compute the pseudo-range corrections for the i^{th} ranging source, excluding the j^{th} reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.1.3 *Definition of K multipliers for Category I precision approach and APV.* The multipliers are given in Table B-67.

Table B-67. K-multipliers for Category I precision approach and APV

	M_i			
Multiplier	1 (Note)	2	3	4
K_{ffmd}	6.86	5.762	5.81	5.847
K_{md}	Not used	2.935	2.898	2.878

Note.— For APV I approaches supported by Type 101 messages broadcast without the B parameter block.

3.6.5.5.2 *GBAS positioning service.* The signal-in-space horizontal protection level is an upper confidence bound on the horizontal error in the position relative to the GBAS reference point defined as:

$$HPL = MAX\{HPL_{H0}, HPL_{H1}\}$$

3.6.5.5.2.1 *Normal measurements conditions.* The horizontal protection level (HPL_{H0}), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$HPL_{H0} = K_{ffmd,\,POS}\, d_{major}$$

where: $d_{mayor} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$

$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$

$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$

$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$

$s_{x,i}$ = the partial derivative of position error in the x-direction with respect to pseudo-range error on the i^{th} satellite

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the i^{th} satellite

$K_{ffmd,POS}$ = the multiplier derived from the probability of fault-free missed detection

N = the number of ranging sources used in the position solution

i = the ranging source index for ranging sources used in the position solution

σ_i = the pseudo-range error term as defined in 3.6.5.5.1.1

Note.— For the GBAS positioning service, the x and y axes define an arbitrary orthogonal basis in the horizontal plane.

3.6.5.5.2.2 *Faulted measurement conditions.* When the Type 101 message is broadcast without B parameter blocks, the value for HPL_{H1} is defined as zero. Otherwise, the horizontal protection level (HPL_{H1}), assuming that a latent fault exists in one and only one reference receiver, is:

$$HPL_{H1} = \max [HPL_j]$$

where HPL_j for j = 1 to 4 is:

$$HPL_j = |B\_horz_j| + K_{md\_POS}\, d_{major,H1}$$

and

$$B\_horz_j = \sqrt{\left(\sum_{i=1}^{N} S_{x,i} B_{i,j}\right)^2 + \left(\sum_{i=1}^{N} S_{y,i} B_{i,j}\right)^2}$$

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the j^{th} reference receiver measurement for the i^{th} ranging source.

K_{md_POS} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted.

$$d_{mayor,H1} = \sqrt{\frac{d\_H1_x^2 + d\_H1_y^2}{2} + \sqrt{\left(\frac{d\_H1_x^2 - d\_H1_y^2}{2}\right)^2 + d\_H1_{xy}^2}}$$

$$d\_H1_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma\_H1_i^2$$

$$d\_H1_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma\_H1_i^2$$

$$d\_H1_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma\_H1_i^2$$

Note.— For the GBAS positioning service, the x and y axes define an arbitrary orthogonal basis in the horizontal plane.

$$\sigma\_H1_i^2 = \left(\frac{M_i}{U_i}\right)\sigma_{pr\_gnd,i}^2 + \sigma_{pr\_air,i}^2 + \sigma_{tropo,i}^2 + \sigma_{iono,i}^2$$

M_i = the number of reference receivers used to compute the pseudo-range corrections for the i^{th} ranging source (indicated by the B values).

U_i = the number of reference receivers used to compute the pseudo-range corrections for the i^{th} ranging source, excluding the j^{th} reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.2.3 *Definition of K multipliers for GBAS positioning service.* The multiplier K_{ffmd_POS} is equal to 10.0 and the multiplier K_{md_POS}, is equal to 5.3.

3.6.5.6 ALERT LIMITS

Note.— Guidance concerning the calculation of alert limits, including approaches associated with channel numbers 40 000 to 99 999, is provided in Attachment D, 7.13.

3.6.5.6.1 *Category I precision approach alert limits.* The alert limits are defined in Tables B-68 and B-69. For aircraft positions at which the lateral deviation exceeds twice the deviation at which full-scale lateral deflection of a course deviation indicator is achieved, or vertical deviation exceeds twice the deviation at which full-scale fly-down deflection of a course deviation indicator is achieved, both the lateral and vertical alert limits are set to the maximum values given in the tables.

Table B-68. Category I lateral alert limit

Horizontal distance of aircraft position from the LTP/FTP as translated along the final approach path (metres)	Lateral alert limit (metres)
$291 < D \leq 873$	FASLAL
$873 < D \leq 7\,500$	0.0044D (m) + FASLAL – 3.85
$D > 7\,500$	FASLAL + 29.15

Table B-69. Category I vertical alert limit

Height above LTP/FTP of aircraft position translated onto the final approach path (feet)	Vertical alert limit (metres)
$100 < H \leq 200$	FASVAL
$200 < H \leq 1\,340$	0.02925H (ft) + FASVAL – 5.85
$H > 1\,340$	FASVAL + 33.35

3.6.5.6.2 *APV alert limits*. The alert limits are equal to the FASLAL and FASVAL for approaches with channel numbers in the range of 20 001 to 39 999. For approaches with channel numbers in the range 40 000 to 99 999, the alert limits are stored in the on-board database.

3.6.5.7 *Channel number*. Each GBAS approach transmitted from the ground subsystem is associated with a channel number in the range of 20 001 to 39 999. If provided, the GBAS positioning service is associated with a separate channel number in the range of 20 001 to 39 999. The channel number is given by:

$$\text{Channel number} = 20\,000 + 40(F - 108.0) + 411(S)$$

where

F = the data broadcast frequency (MHz)
S = RPDS or RSDS

and

RPDS = the reference path data selector for the FAS data block (as defined in 3.6.4.5.1)
RSDS = the reference station data selector for the GBAS ground subsystem (as defined in 3.6.4.3.1)

For channel numbers transmitted in the additional data block 2 of Type 2 message (as defined in 3.6.4.3.2.1), only RSDS are used.

Note 1.— When the FAS is not broadcast for an APV, the GBAS approach is associated with a channel number in the range 40 000 to 99 999.

Note 2.— Guidance material concerning channel number selection is provided in Attachment D, 7.7.

3.6.5.8 *EPHEMERIS ERROR POSITION BOUND*

Note.— Ephemeris error position bounds are computed only for core satellite constellation ranging sources used in the position solution (j index) and not for other types of ranging sources (SBAS satellites or pseudolites) that are not subject to undetected ephemeris failures. However, the calculations of these position bounds use information from all ranging sources used in the position solution (i index).

3.6.5.8.1 *Category I precision approach and APV.* The vertical and lateral ephemeris error position bounds are defined as:

$$VEB = \underset{j}{MAX}\{VEB_j\}$$

$$LEB = \underset{j}{MAX}\{LEB_j\}$$

The vertical and lateral ephemeris error position bounds for the j[th] core satellite constellation ranging source used in the position solution are given by:

$$VEB_j = \left|s\_vert_j\right| x_{air} P_j + K_{md\_e,j} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LEB_j = \left|s\_lat_j\right| x_{air} P_j + K_{md\_e,j} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where:

$s\_vert_{i\ or\ j}$ is defined in 3.6.5.5.1.1
$s\_lat_{i\ or\ j}$ is defined in 3.6.5.5.1.1
x_{air} is defined in 3.6.5.4
N is the number of ranging sources used in the position solution
σ_i is defined in 3.6.5.5.1.1
P_j is the broadcast ephemeris decorrelation parameter for the j[th] ranging source
$K_{md\_e,j}$ is the broadcast ephemeris missed detection multiplier for Category I precision approach and APV associated with the satellite constellation for the j[th] ranging source ($K_{md\_e,GPS}$ or $K_{md\_e,GLONASS}$)

3.6.5.8.2 *GBAS positioning service*. The horizontal ephemeris error position bound is defined as:

$$HEB = \underset{j}{MAX}\{HEB_j\}$$

The horizontal ephemeris error position bound for the j[th] core satellite constellation ranging source used in the position solution is given by:

$$HEB_j = \left|s_{horz,j}\right| x_{air} P_j + K_{md\_e\_POS} d_{mayor}$$

where:

$S_{horz,j}{}^2 = S_{xj}{}^2 + S_{yj}{}^2$
$s_{x,j}$ is as defined in 3.6.5.5.2.1
$s_{y,j}$ is as defined in 3.6.5.5.2.1
x_{air} is defined in 3.6.5.4
P_j is the broadcast ephemeris decorrelation parameter for the j[th] ranging source
$K_{md\_e\_POS}$ is the broadcast ephemeris missed detection multiplier for the GBAS positioning service associated with the satellite constellation for the j[th] ranging source ($K_{md\_e\_POS,GPS}$ or $K_{md\_e\_POS,GLONASS}$)
d_{major} is as defined in 3.6.5.5.2.1

3.6.6 MESSAGE TABLES

Each GBAS message shall be coded in accordance with the corresponding message format defined in Tables B-70 through B-73.

Note.— Message type structure is defined in 3.6.4.1.

Table B-70. Type 1 pseudo-range corrections message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Additional message flag	2	0 to 3	1
Number of measurements (N)	5	0 to 18	1
Measurement type	3	0 to 7	1
Ephemeris decorrelation parameter (P)	8	0 to 1.275 × 10^{-3} m/m	5 × 10^{-6} m/m
Ephemeris CRC	16	—	—
Source availability duration	8	0 to 2 540 s	10 s
For N measurement blocks			
Ranging source ID	8	1 to 255	1
Issue of data (IOD)	8	0 to 255	1
Pseudo-range 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}	8	0 to 5.08 m	0.02 m
B_1	8	±6.35 m	0.05 m
B_2	8	±6.35 m	0.05 m
B_3	8	±6.35 m	0.05 m
B_4	8	±6.35 m	0.05 m

Table B-70A. Type 101 GRAS pseudo-range corrections message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Additional message flag	2	0 to 3	1
Number of measurements (N)	5	0 to 18	1
Measurement type	3	0 to 7	1
Ephemeris decorrelation parameter (P)	8	0 to 1.275 × 10^{-3} m/m	5 × 10^{-6} m/m
Ephemeris CRC	16	—	—
Source availability duration	8	0 to 2540 s	10 s
Number of B parameters	1	0 or 4	—
Spare	7	—	—
For N measurement blocks			
Ranging source ID	8	1 to 255	1
Issue of data (IOD)	8	0 to 255	1
Pseudo-range 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}	8	0 to 50.8 m	0.2 m
B parameter block (if provided)			
B_1	8	±25.4 m	0.2 m
B_2	8	±25.4 m	0.2 m
B_3	8	±25.4 m	0.2 m
B_4	8	±25.4 m	0.2 m

Table B-71A. Type 2 GBAS-related data message

Data content	Bits used	Range of values	Resolution
GBAS reference receivers	2	2 to 4	—
Ground accuracy designator letter	2	—	—
Spare	1	—	—
GBAS continuity/integrity designator	3	0 to 7	1
Local magnetic variation	11	±180°	0.25°
Spare	5	—	—
$\sigma_{vert\ iono\ gradient}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m
Refractivity index	8	16 to 781	3
Scale height	8	0 to 25 500 m	100 m
Refractivity uncertainty	8	0 to 255	1
Latitude	32	±90.0°	0.0005 arcsec
Longitude	32	±180.0°	0.0005 arcsec
GBAS reference point height	24	±83 886.07 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
$K_{md\ e,GPS}$	8	0 to 12.75	0.05
$K_{md\ e\ POS,GLONASS}$	8	0 to 12.75	0.05
$K_{md\ e,GLONASS}$	8	0 to 12.75	0.05
Additional data block 2 (if provided)			
Additional data block length	8	2 to 255	1
Additional data block number	8	2 to 255	1
Additional data parameters	Variable	—	—

Table B-71B. Type 3 null message

Data content	Bits used	Range of values	Resolution
Filler	Variable (Note)	N/A	N/A

Note.— The number of bytes in the filler field is 10 less than the message length field in the message header as defined in section 3.6.3.4.

Table B-72. Type 4 FAS data message

Data content	Bits used	Range of values	Resolution
For N data sets			
Data set length	8	2 to 212	1 byte
FAS data block	304	—	—
FAS vertical alert limit/approach status	8		
(1) when associated approach performance designator indicates APV-I (APD coded as 0)		0 to 50.8 m	0.2 m
(2) when associated approach performance designator does not indicate APV-I (APD not coded as 0)		0 to 25.4 m	0.1 m
FAS lateral alert limit/approach status	8	0 to 50.8 m	0.2 m

Table B-73. Type 5 predicted ranging source availability message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Spare	2	—	—
Number of impacted sources (N)	8	0 to 31	1
For N impacted sources			
Ranging source ID	8	1 to 255	1
Source availability sense	1	—	—
Source availability duration	7	0 to 1 270 s	10 s
Number of obstructed approaches (A)	8	0 to 255	1
For A obstructed approaches			
Reference path data selector	8	0 to 48	—
Number of impacted sources for this approach (N_A)	8	1 to 31	1
For N_A impacted ranging sources for this approach			
Ranging source ID	8	1 to 255	1
Source availability sense	1	—	—
Source availability duration	7	0 to 1 270 s	10 s

3.6.7 NON-AIRCRAFT ELEMENTS

3.6.7.1 *PERFORMANCE*

3.6.7.1.1 *Accuracy*

3.6.7.1.1.1 The root-mean-square (RMS) (1 sigma) of the ground subsystem contribution to the corrected pseudo-range accuracy for GPS and GLONASS satellites shall be:

$$RMS_{pr\_gnd} \le \sqrt{\frac{(a_0 + a_1 e^{-\theta_n/\theta_0})^2}{M} + (a_2)^2}$$

where

M	=	the number of GNSS reference receivers, as indicated in the Type 2 message parameter (3.6.4.3), or, when this parameter is coded to indicate "not applicable", the value of M is defined as 1;
n	=	n^{th} ranging source;
θ_n	=	elevation angle for the n^{th} ranging source; and
a_0, a_1, a_2, and θ_0	=	parameters defined in Tables B-74 and B-75 for each of the defined ground accuracy designators (GADs).

Note 1.— The GBAS ground subsystem accuracy requirement is determined by the GAD letter and the number of installed reference receivers.

Note 2.— The ground subsystem contribution to the corrected pseudo-range error specified by the curves defined in Tables B-74 and B-75 and the contribution to the SBAS satellites do not include aircraft noise and aircraft multipath.

Table B-74. GBAS — GPS accuracy requirement parameters

Ground accuracy designator letter	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)	a_2 (metres)
A	≥ 5	0.5	1.65	14.3	0.08
B	≥ 5	0.16	1.07	15.5	0.08
C	> 35	0.15	0.84	15.5	0.04
	5 to 35	0.24	0	—	0.04

Table B-75. GBAS — GLONASS accuracy requirement parameters

Ground accuracy designator letter	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)	a_2 (metres)
A	≥ 5	1.58	5.18	14.3	0.078
B	≥ 5	0.3	2.12	15.5	0.078
C	> 35	0.3	1.68	15.5	0.042
	5 to 35	0.48	0	—	0.042

3.6.7.1.1.2 The RMS of the ground subsystem contribution to the corrected pseudo-range accuracy for SBAS satellites shall be:

$$RMS_{pr\_gnd} \le \frac{1.8}{\sqrt{M}} \text{ (metres)}$$

where M is as defined in 3.6.7.1.1.1.

Note.— GAD classifications for SBAS ranging sources are under development.

3.6.7.1.2 *Integrity*

3.6.7.1.2.1 *GBAS ground subsystem integrity risk*

3.6.7.1.2.1.1 *Category I precision approach and APV.* For a GBAS ground subsystem that provides the Category I precision approach or APV, the integrity risk shall be less than 1.5×10^{-7} per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.2.6 and the integrity risk associated with the monitoring in 3.6.7.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft, results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the Category I precision approach or APV protection level and, if additional data block 1 is broadcast, the ephemeris error position bound.

3.6.7.1.2.1.1.1 The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast.

Note.— The time-to-alert above is the time between the onset of the out-of-tolerance lateral or vertical relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition.

3.6.7.1.2.1.1.2 The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 5.5 seconds when Type 101 messages are broadcast.

3.6.7.1.2.1.1.3 For Category I precision approach, the value FASLAL for each FAS block, as defined in the FAS lateral alert limit field of the Type 4 message shall be no greater than 40 metres, and the value FASVAL for each FAS block, as defined in the FAS vertical alert limit field of the Type 4 message, shall be no greater than 10 metres.

3.6.7.1.2.1.1.4 For APV, the value FASLAL and FASVAL shall be no greater than the lateral and vertical alert limits given in Annex 10, Volume I, 3.7.2.4.

3.6.7.1.2.1.2 *GBAS positioning service*. For GBAS ground subsystem that provides the GBAS positioning service, integrity risk shall be less than 9.9×10^{-8} per hour.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.2) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.2.6 and the integrity risk associated with the monitoring in 3.6.7.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft, results in an out-of-tolerance horizontal relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance horizontal relative position error is defined as an error that exceeds both the horizontal protection level and the horizontal ephemeris error position bound.

3.6.7.1.2.1.2.1 The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast and less than or equal to 5.5 seconds when Type 101 messages are broadcast.

Note.— The time-to-alert above is the time between the onset of the out-of-tolerance horizontal relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition.

3.6.7.1.2.2 *Protection level integrity risk*

3.6.7.1.2.2.1 For a GBAS ground subsystem that provides the Category I precision approach or APV, the protection level integrity risk shall be less than 5×10^{-8} per approach.

Note.— The Category I precision approach and APV protection level integrity risk is the integrity risk due to undetected errors in position relative to the GBAS reference point greater than the associated protection levels under the two following conditions:

a) normal measurement conditions defined in 3.6.5.5.1.1; and

b) faulted measurement conditions defined in 3.6.5.5.1.2.

3.6.7.1.2.2.2 For a GBAS ground subsystem that provides the positioning service, protection level integrity risk shall be less than 10^{-9} per hour.

Note.— The GBAS positioning service protection level integrity risk is the integrity risk due to undetected errors in the horizontal position relative to the GBAS reference point greater than the GBAS positioning service protection level under the two following conditions:

a) normal measurement conditions defined in 3.6.5.5.2.1; and

b) faulted measurement conditions defined in 3.6.5.5.2.2.

3.6.7.1.3 *Continuity of service*

3.6.7.1.3.1 *Continuity of service for Category I precision approach and APV.* The GBAS ground subsystem continuity of service shall be greater than or equal to $1 - 8.0 \times 10^{-6}$ per 15 seconds.

Note.— The GBAS ground subsystem continuity of service is the average probability per 15-second period that the VHF data broadcast transmits data in tolerance, VHF data broadcast field strength is within the specified range and the protection levels are lower than the alert limits, including configuration changes that occur due to the space segment. This continuity of service requirement is the entire allocation of the signal-in-space continuity requirement from Chapter 3, Table 3.7.2.4-1, and therefore all continuity risks included in that requirement must be accounted for by the ground subsystem provider.

3.6.7.1.3.2 *Continuity of service for positioning service*

Note.— For GBAS ground subsystems that provide the GBAS positioning service, there may be additional continuity requirements depending on the intended operations.

3.6.7.2 *FUNCTIONAL REQUIREMENTS*

3.6.7.2.1 *General*

3.6.7.2.1.1 *Data broadcast rates*

3.6.7.2.1.1.1 A GBAS ground subsystem that supports Category I precision approach or APV-II shall broadcast Type 1 messages. A GBAS ground subsystem that does not support Category I precision approach or APV-II shall broadcast either Type 1 or Type 101 messages. A GBAS ground subsystem shall not broadcast both Type 1 and Type 101 messages.

Note.— Guidance material concerning usage of the Type 101 message is provided in Attachment D, 7.18.

3.6.7.2.1.1.2 Each GBAS ground subsystem shall broadcast Type 2 messages.

3.6.7.2.1.1.3 Each GBAS ground subsystem shall broadcast FAS blocks in Type 4 messages for all Category I precision approaches supported by that GBAS ground subsystem. If a GBAS ground subsystem supports APV and does not broadcast FAS blocks for the corresponding approaches, it shall broadcast additional data block 1 in the Type 2 message.

Note.— FAS blocks for APV procedures may be held within a database on board the aircraft. Broadcasting additional data block 1 allows the airborne receiver to select the GBAS ground subsystem that supports the approach procedures in the airborne database. FAS blocks may also be broadcast to support operations by aircraft without an airborne database. These procedures use different channel numbers as described in Attachment D, 7.7.

3.6.7.2.1.1.4 When the Type 5 message is used, the ground subsystem shall broadcast the Type 5 message at a rate in accordance with Table B-76.

Note.— When the standard 5 degree mask is not adequate to describe satellite visibility at either the ground subsystem antennas or at an aircraft during a specific approach, the Type 5 message may be used to broadcast additional information to the aircraft.

3.6.7.2.1.1.5 *Data broadcast rates.* For all message types required to be broadcast, messages meeting the field strength requirements of Chapter 3, 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 and the minimum rates shown in Table B-76 shall be provided at every point within the coverage. The total message broadcast rates from all antenna systems of the ground subsystem combined shall not exceed the maximum rates shown in Table B-76.

Note.— Guidance material concerning the use of multiple antenna systems is provided in Attachment D, 7.12.4.

Table B-76. GBAS VHF data broadcast rates

Message type	Minimum broadcast rate	Maximum broadcast rate
1 or 101	For each measurement type: All measurement blocks once per frame (Note)	For each measurement type: All measurement blocks once per slot
2	Once per 20 consecutive frames	Once per frame
4	All FAS blocks once per 20 consecutive frames	All FAS blocks once per frame
5	All impacted sources once per 20 consecutive frames	All impacted sources once per 5 consecutive frames

Note.— One Type 1 or Type 101 message or two Type 1 or Type 101 messages that are linked using the additional message flag described in 3.6.4.2.

3.6.7.2.1.2 *Message block identifier.* The MBI shall be set to either normal or test according to the coding given in 3.6.3.4.1.

3.6.7.2.1.3 *VDB authentication*

Note.— This section is reserved for forward compatibility with future authentication functions.

3.6.7.2.2 *Pseudo-range corrections*

3.6.7.2.2.1 *Message latency*. The time between the time indicated by the modified Z-count and the last bit of the broadcast Type 1 or Type 101 message shall not exceed 0.5 seconds.

3.6.7.2.2.2 *Low-frequency data*. Except during an ephemeris change, the first ranging source in the message shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 10 seconds. During an ephemeris change, the first ranging source shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 27 seconds. When new ephemeris data are received from a core satellite constellation's ranging source, the ground subsystem shall use the previous ephemeris data from each satellite until the new ephemeris data have been continuously received for at least 2 minutes but shall make a transition to the new ephemeris data before 3 minutes have passed. When this transition is made to using the new ephemeris data for a given ranging source, the ground subsystem shall broadcast the new ephemeris CRC for all occurrences of that ranging source in the low-frequency information of Type 1 or Type 101 message in the next 3 consecutive frames. For a given ranging source, the ground subsystem shall continue to transmit data corresponding to the previous ephemeris data until the new CRC ephemeris is transmitted in the low-frequency data of Type 1 or Type 101 message (see Note). If the ephemeris CRC changes and the IOD does not, the ground subsystem shall consider the ranging source invalid.

Note.— The delay before the ephemeris transition allow sufficient time for the aircraft subsystem to collect new ephemeris data.

3.6.7.2.2.2.1 **Recommendation.—** *The ephemeris decorrelation parameter and the ephemeris CRC for each core satellite constellation's ranging source should be broadcast as frequently as possible.*

3.6.7.2.2.3 *Broadcast pseudo-range correction*. Each broadcast pseudo-range correction shall be determined by combining the pseudo-range correction estimates for the relevant ranging source calculated from each of the reference receivers. For each satellite, the measurements used in this combination shall be obtained from the same ephemeris data. The corrections shall be based on smoothed code pseudo-range measurements for each satellite using the carrier measurement from a smoothing filter in accordance with 3.6.5.1.

3.6.7.2.2.4 *Broadcast signal-in-space integrity parameters*. The ground subsystem shall provide σ_{pr_gnd} and B parameters for each pseudo-range correction in Type 1 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied. The ground subsystem shall provide σ_{pr_gnd} and, if necessary, B parameters for each pseudo-range correction in Type 101 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

Note.— Broadcast of the B parameters are optional for Type 101 messages. Guidance material regarding the B parameters in Type 101 messages is contained in Attachment D, 7.5.11.

3.6.7.2.2.5 **Recommendation.—** *Reference receiver measurements should be monitored. Faulted measurements or failed reference receivers should not be used to compute the pseudo-range corrections.*

3.6.7.2.2.6 *Repeated transmission of Type 1 or Type 101 messages.* For a given measurement type and within a given frame, all broadcasts of Type 1 or Type 101 messages or linked pairs from all GBAS broadcast stations that share a common GBAS identification, shall have identical data content.

3.6.7.2.2.7 *Issue of data.* The GBAS ground subsystem shall set the IOD field in each ranging source measurement block to be the IOD value received from the ranging source that corresponds to the ephemeris data used to compute the pseudo-range correction.

3.6.7.2.2.8 *Application of signal error models*. Ionospheric and tropospheric corrections shall not be applied to the pseudo-ranges used to calculate the pseudo-range corrections.

3.6.7.2.2.9 *Linked pair of Type 1 or Type 101 messages.* If a linked pair of Type 1 or Type 101 messages is transmitted then,

a) the two messages shall have the same modified Z-count;

b) the minimum number of pseudo-range corrections in each message shall be one;

c) the measurement block for a given satellite shall not be broadcast more than once in a linked pair of messages;

d) the two messages shall be broadcast in different time slots; and

e) the order of the B values in the two messages shall be the same.

3.6.7.2.2.10 *Modified Z-count update.* The modified Z-count for Type 1 or Type 101 messages of a given measurement type shall advance every frame.

3.6.7.2.2.11 *Ephemeris decorrelation parameters*

3.6.7.2.2.11.1 *Category I precision approach and APV*. For ground subsystems that broadcast the additional data block 1 in the Type 2 message, the ground subsystem shall broadcast the ephemeris decorrelation parameter for each core satellite constellation ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.1 is met.

3.6.7.2.2.11.2 *GBAS positioning service*. For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris decorrelation parameter for each core satellite constellation's ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.2 is met.

3.6.7.2.3 *GBAS-related data*

3.6.7.2.3.1 *Tropospheric delay parameters.* The ground subsystem shall broadcast a refractivity index, scale height, and refractivity uncertainty in a Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.2 *GCID indication*. If the ground subsystem meets the requirements of 3.6.7.1.2.1.1, 3.6.7.1.2.2.1 and 3.6.7.1.3.1 the GCID shall be set to 1 otherwise it shall be set to 7.

3.6.7.2.3.3 *GBAS reference antenna phase centre position accuracy*. For each GBAS reference receiver, the reference antenna phase centre position error shall be less than 8 cm relative to the GBAS reference point.

3.6.7.2.3.4 **Recommendation.—** *GBAS reference point survey accuracy. The survey error of the GBAS reference point, relative to WGS-84, should be less than 0.25 m vertical and 1 m horizontal.*

Note.— Relevant guidance material is given in Attachment D, 7.16.

3.6.7.2.3.5 *Ionospheric uncertainty estimate parameter.* The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.6 For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris error position bound parameters using additional data block 1 in the Type 2 message.

3.6.7.2.3.7 **Recommendation.—** *All ground subsystems should broadcast the ephemeris error position bound parameters using additional data block 1 in the Type 2 message.*

3.6.7.2.3.8 For ground subsystems that broadcast additional data block 1 in the Type 2 message, the following requirements shall apply:

3.6.7.2.3.8.1 *Maximum use distance*. The ground subsystem shall provide the distance (D_{max}) from the GBAS reference point that defines a volume within which the ground subsystem integrity risk in 3.6.7.1.2.1 and the protection level integrity risk in 3.6.7.1.2.2 are met.

3.6.7.2.3.8.2 *Ephemeris missed detection parameters*. The ground subsystem shall broadcast the ephemeris missed detection parameters for each core satellite constellation such that the ground subsystem integrity risk of 3.6.7.1.2.1 is met.

3.6.7.2.3.8.3 *GBAS positioning service indication*. If the ground subsystem does not meet the requirements of 3.6.7.1.2.1.2 and 3.6.7.1.2.2.2, the ground subsystem shall indicate using the RSDS parameter that the GBAS positioning service is not provided.

3.6.7.2.3.9 If the VHF data broadcast is transmitted at more than one frequency within the GRAS service area, each GBAS broadcast station within the GRAS ground subsystem shall broadcast additional data blocks 1 and 2.

3.6.7.2.3.9.1 **Recommendation.—** *The VHF data broadcast should include additional data block 2 parameters to identify channel numbers and locations of adjacent and nearby GBAS broadcast stations within the GRAS ground subsystem.*

Note.— This facilitates the transition from one GBAS broadcast station to other GBAS broadcast stations in the GRAS ground subsystem.

3.6.7.2.4 *Final approach segment data*

3.6.7.2.4.1 *FAS data points accuracy*. The relative survey error between the FAS data points and the GBAS reference point shall be less than 0.25 metres vertical and 0.40 metres horizontal.

3.6.7.2.4.2 *SBAS FAS data points accuracy.* For use with SBAS, the survey error of all the FAS data points, relative to WGS-84, shall be less than 0.25 metres vertical and 1 metre horizontal.

3.6.7.2.4.3 **Recommendation.—** *The final approach segment CRC should be assigned at the time of procedure design, and kept as an integral part of the FAS data block from that time onward.*

3.6.7.2.4.4 **Recommendation.—** *The GBAS should allow the capability to set the FASVAL and FASLAL for any FAS data block to "1111 1111" to limit the approach to lateral only or to indicate that the approach must not be used, respectively.*

3.6.7.2.5 *Predicted ranging source availability data*

Note.— Ranging source availability data are optional for Category I and APV and may be required for possible future operations.

3.6.7.2.6 *Integrity monitoring for GNSS ranging sources*. The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers complying with the tracking constraints in Attachment D, 8.11. The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo-range corrections. The monitor time-to-alert shall comply with 3.6.7.1.2. The monitor action shall be to set σ_{pr_gnd} to the bit pattern "1111 1111" for the satellite or to exclude the satellite from the Type 1 or Type 101 message. The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as described in Attachment D, 8.11.

3.6.7.3 *MONITORING*

3.6.7.3.1 *RF monitoring*

3.6.7.3.1.1 *VHF data broadcast monitoring.* The data broadcast transmissions shall be monitored. The transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 3-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission.

3.6.7.3.1.2 *TDMA slot monitoring.* The risk that the ground subsystem transmits a signal in an unassigned slot and fails to detect an out-of-slot transmission, which exceeds that allowed in 3.6.2.6, within 1 second, shall be less than 1×10^{-7} in any 30-second period. If out-of-slot transmissions are detected, the ground subsystem shall terminate all data broadcast transmissions within 0.5 seconds.

3.6.7.3.1.3 *VDB transmitter power monitor.* The probability that the horizontally or elliptically polarized signal's transmitted power increases by more than 3 dB from the nominal power for more than 1 second shall be less than 2.0×10^{-7} in any 30-second period.

Note.— The vertical component is only monitored for GBAS/E equipment.

3.6.7.3.2 *Data monitoring*

3.6.7.3.2.1 *Broadcast quality monitor*. The ground subsystem monitoring shall comply with the time-to-alert requirements given in 3.6.7.1.2.1. The monitoring action shall be one of the following:

a) to broadcast Type 1 or Type 101 messages with no measurement blocks; or

b) to broadcast Type 1 or Type 101 messages with the $\sigma_{pr\_gnd,i}$ field set to indicate the ranging source is invalid for every ranging source included in the previously transmitted frame; or

c) to terminate the data broadcast.

Note.— Monitoring actions a) and b) are preferred to c) if the particular failure mode permits such a response, because actions a) and b) typically have a reduced signal-in-space time-to-alert.

3.6.7.4 *FUNCTIONAL REQUIREMENTS FOR AUTHENTICATION PROTOCOLS*

3.6.7.4.1 *Functional requirements for ground subsystems that support authentication*

3.6.7.4.1.1 The ground system shall broadcast the additional data block 4 with the Type 2 message with the slot group definition field coded to indicate which slots are assigned to the ground station.

3.6.7.4.1.2 The ground subsystem shall broadcast every Type 2 message in the slot that corresponds to the SSID coding for the ground subsystem. Slot A is represented by SSID = 0, B by 1, C by 2, and H by 7.

3.6.7.4.1.3 *Assigned slot occupancy*. The ground subsystem shall transmit messages such that 87 per cent or more of every assigned slot is occupied. If necessary, Type 3 messages will be used to fill unused space in any assigned time slot.

3.6.7.4.1.4 *Reference path identifier coding*. Every reference path identifier included in every final approach segment data block broadcast by the ground station via the Type 4 messages shall have the first letter selected to indicate the SSID of the ground station in accordance with the following coding.

Coding: A = SSID of 0
X = SSID of 1
Z = SSID of 2
J = SSID of 3
C = SSID of 4
V = SSID of 5
P = SSID of 6
T = SSID of 7

3.6.7.4.2 *Functional requirements for ground subsystems that do not support authentication*

3.6.7.4.2.1 *Reference path indicator coding*. Characters in this set: {A X Z J C V P T} shall not be used as the first character of the reference path identifier included in any FAS block broadcast by the ground station via the Type 4 messages.

3.6.8 AIRCRAFT ELEMENTS

3.6.8.1 *GNSS receiver.* The GBAS-capable GNSS receiver shall process signals of GBAS in accordance with the requirements specified in this section as well as with requirements in 3.1.3.1 and/or 3.2.3.1 and/or 3.5.8.1.

3.6.8.2 *PERFORMANCE REQUIREMENTS*

3.6.8.2.1 *GBAS aircraft receiver accuracy*

3.6.8.2.1.1 The RMS of the total aircraft receiver contribution to the error for GPS and GLONASS shall be:

$$RMS_{pr\_air}(\theta_n) \leq a_0 + a_1 \times e^{-(\theta_n/\theta_0)}$$

where

n = the n^{th} ranging source;
θ_n = the elevation angle for the n^{th} ranging source; and
a_0, a_1, and θ_0 = as defined in Table B-77 for GPS and Table B-78 for GLONASS.

3.6.8.2.1.2 The RMS of the total aircraft receiver contribution to the error for SBAS satellites shall be as defined in 3.5.8.2.1 for each of the defined aircraft accuracy designators.

Note.— The aircraft receiver contribution does not include the measurement error induced by airframe multipath.

Table B-77. Aircraft GPS receiver accuracy requirement

Aircraft accuracy designator	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)
A	≥5	0.15	0.43	6.9
B	≥5	0.11	0.13	4

Table B-78. Aircraft GLONASS receiver accuracy requirement

Aircraft accuracy designator	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)
A	≥5	0.39	0.9	5.7
B	≥5	0.105	0.25	5.5

3.6.8.2.2 *VHF data broadcast receiver performance*

3.6.8.2.2.1 *VHF data broadcast tuning range.* The VHF data broadcast receiver shall be capable of tuning frequencies in the range of 108.000 – 117.975 MHz in increments of 25 kHz.

3.6.8.2.2.2 *VHF data broadcast capture range.* The VHF data broadcast receiver shall be capable of acquiring and maintaining lock on signals within ±418 Hz of the nominal assigned frequency.

Note.— The frequency stability of the GBAS ground subsystem, and the worst-case doppler shift due to the motion of the aircraft, are reflected in the above requirement. The dynamic range of the automatic frequency control should also consider the frequency-stability error budget of the aircraft VHF data broadcast receiver.

3.6.8.2.2.3 *VHF data broadcast sensitivity, range and message failure rate*. The VHF data broadcast receiver shall achieve a message failure rate less than or equal to one failed message per 1 000 full-length (222 bytes) application data messages, while operating over a range from –87 dBm to –1 dBm, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed 40 dB. Failed messages include those lost by the VHF data broadcast receiver system or which do not pass the CRC after application of the FEC.

Note.— Aircraft VHF data broadcast receiving antenna can be horizontally or vertically polarized. Due to the difference in the signal strength of horizontally and vertically polarized components of the broadcast signal, the total aircraft implementation loss is limited to 15 dB for horizontally polarized receiving antennas and 11 dB for vertically polarized receiving antennas.

3.6.8.2.2.4 *VHF data broadcast time slot decoding*. The VHF data broadcast receiver shall meet the requirements of 3.6.8.2.2.3 for all Type 1, 2 and 4 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

Note.— Other GBAS transmissions may include: a) messages other than Type 1, 2 and 4 with the same SSID, and b) messages with different SSIDs.

3.6.8.2.2.4.1 *Decoding of Type 101 messages*. A VHF data broadcast receiver capable of receiving Type 101 messages, shall meet the requirements of 3.6.8.2.2.3 for all Type 101 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

3.6.8.2.2.5 *Co-channel rejection*

3.6.8.2.2.5.1 *VHF data broadcast as the undesired signal source*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VHF data broadcast signal that is either:

a) assigned to the same time slot(s) and 26 dB below the desired VHF data broadcast signal power or lower; or

b) assigned different time slot(s) and whose power is up to 15 dBm at the receiver input.

3.6.8.2.2.5.2 *VOR as the undesired signal*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VOR signal that is 26 dB below the desired VHF data broadcast signal power.

3.6.8.2.2.6 *Adjacent channel rejection*

3.6.8.2.2.6.1 *First adjacent 25 kHz channels (±25 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 25 kHz on either side of the desired channel that is either:

a) 18 dB above the desired signal power when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) equal in power when the undesired signal is VOR.

3.6.8.2.2.6.2 *Second adjacent 25 kHz channels (±50 kHz)*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel that is either:

a) 43 dB above the desired signal power when the undesired signal is another VHF data broadcast source assigned to the same time slot(s); or

b) 34 dB above the desired signal power when the undesired signal is VOR.

3.6.8.2.2.6.3 *Third and beyond adjacent 25 kHz channels (±75 kHz or more)*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel that is either:

a) 46 dB above the desired signal power when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) 46 dB above the desired signal power when the undesired signal is VOR.

3.6.8.2.2.7 *Rejection of off-channel signals from sources inside the 108.000 – 117.975 MHz band.* With no on-channel VHF data broadcast signal present, the VHF data broadcast receiver shall not output data from an undesired VHF data broadcast signal on any other assignable channel.

3.6.8.2.2.8 *Rejection of signals from sources outside the 108.000 – 117.975 MHz band*

3.6.8.2.2.8.1 *VHF data broadcast interference immunity.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of one or more signals having the frequency and total interference levels specified in Table B-79.

3.6.8.2.2.8.2 *Desensitization*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of VHF FM broadcast signals with signal levels shown in Tables B-80 and B-81.

Table B-79. Maximum levels of undesired signals

Frequency	Maximum level of undesired signals at the receiver input (dBm)
50 kHz up to 88 MHz	–13
88 MHz – 107.900 MHz	(see 3.6.8.2.2.8.2)
108.000 MHz – 117.975 MHz	excluded
118.000 MHz	–44
118.025 MHz	–41
118.050 MHz up to 1 660.5 MHz	–13

Notes.—

1. *The relationship is linear between single adjacent points designated by the above frequencies.*

2. *These interference immunity requirements may not be adequate to ensure compatibility between VHF data broadcast receivers and VHF communication systems, particularly for aircraft that use the vertically polarized component of the VHF data broadcast. Without coordination between COM and NAV frequencies assignments or respect of a guard band at the top end of the 112 – 117.975 MHz band, the maximum levels quoted at the lowest COM VHF channels (118.000, 118.00833, 118.01666, 118.025, 118.03333, 118.04166, 118.05) may be exceeded at the input of the VDB receivers. In that case, some means to attenuate the COM signals at the input of the VDB receivers (e.g. antenna separation) will have to be implemented. The final compatibility will have to be assured when equipment is installed on the aircraft.*

Table B-80. Desensitization frequency and power requirements that apply for VDB frequencies from 108.025 to 111.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dBm)
88 MHz ≤ f ≤ 102 MHz	15
104 MHz	10
106 MHz	5
107.9 MHz	–10

Notes.—

1. *The relationship is linear between single adjacent points designated by the above frequencies.*

2. *This desensitization requirement is not applied for FM carriers above 107.7 MHz and VDB channels at 108.025 or 108.050 MHz. See Attachment D, 7.2.1.2.2.*

Table B-81. Desensitization frequency and power requirements that apply for VDB frequencies from 112.000 to 117.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dBm)
88 MHz ≤ f ≤ 104 MHz	15
106 MHz	10
107 MHz	5
107.9 MHz	0

Note.— The relationship is linear between single adjacent points designated by the above frequencies.

3.6.8.2.2.8.3 *VHF data broadcast FM intermodulation immunity*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of interference from two-signal, third-order intermodulation products of two VHF FM broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 72 \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7 – 108.0 MHz and

$$2N_1 + N_2 + 3\left(24 - 20\log\frac{\Delta f}{0.4}\right) \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VHF data broadcast receiver input. Neither level shall exceed the desensitization criteria set forth in 3.6.8.2.2.8.2.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

Note.— The FM intermodulation immunity requirements are not applied to a VHF data broadcast channel operating below 108.1 MHz, hence frequencies below 108.1 MHz are not intended for general assignments. Additional information is provided in Attachment D, 7.2.1.2.

3.6.8.3 *AIRCRAFT FUNCTIONAL REQUIREMENTS*

3.6.8.3.1 *Conditions for use of data*

3.6.8.3.1.1 The receiver shall use data from a GBAS message only if the CRC of that message has been verified.

3.6.8.3.1.2 The receiver shall use message data only if the message block identifier is set to the bit pattern "1010 1010".

3.6.8.3.1.2.1 *GBAS message processing capability.* The GBAS receiver shall at a minimum process GBAS message types in accordance with Table B-82.

Table B-82. Airborne equipment message type processing

Airborne equipment designed performance	Minimum message types processed
APV-I	MT 1 or 101, MT 2 (including ADB 1 and 2 if provided)
APV-II	MT 1, MT 2 (including ADB 1 and 2 if provided), MT 4
Category I	MT 1, MT 2 (including ADB 1 if provided), MT 4

3.6.8.3.1.2.2 *Airborne processing for forward compatibility*

Note.— Provisions have been made to enable future expansion of the GBAS Standards to support new capabilities. New message types may be defined, new additional data blocks for message Type 2 may be defined and new data blocks defining reference paths for inclusion within message Type 4 may be defined. To facilitate these future expansions, all equipment should be designed to properly ignore all data types that are not recognized.

3.6.8.3.1.2.2.1 *Processing of unknown message types.* The existence of messages unknown to the airborne receiver shall not prevent correct processing of the required messages.

3.6.8.3.1.2.2.2 *Processing of unknown Type 2 extended data blocks.* The existence of message Type 2 additional data blocks unknown to the airborne receiver shall not prevent correct processing of the required messages.

3.6.8.3.1.2.2.3 *Processing of unknown Type 4 data blocks.* The existence of message Type 4 data blocks unknown to the airborne receiver shall not prevent correct processing of the required messages.

Note.— While the current SARPs include only one definition of a data block for inclusion within a Type 4 message, future GBAS Standards may include other reference path definitions.

3.6.8.3.1.3 The receiver shall use only ranging source measurement blocks with matching modified Z-counts.

3.6.8.3.1.4 If D_{max} is broadcast by the ground subsystem, the receiver shall only apply pseudo-range corrections when the distance to the GBAS reference point is less than D_{max}.

3.6.8.3.1.5 The receiver shall only apply pseudo-range corrections from the most recently received set of corrections for a given measurement type. If the number of measurement fields in the most recently received Type 1 or Type 101 message indicates that there are no measurement blocks, then the receiver shall not apply GBAS corrections for that measurement type.

3.6.8.3.1.6 The receiver shall exclude from the differential navigation solution any ranging sources for which σ_{pr_gnd} is set to the bit pattern “1111 1111”.

3.6.8.3.1.7 The receiver shall only use a ranging source in the differential navigation solution if the time of applicability indicated by the modified Z-count in the Type 1 or Type 101 message containing the ephemeris decorrelation parameter for that ranging source is less than 120 seconds old.

3.6.8.3.1.8 *Conditions for use of data to support Category I precision approach and APV*

3.6.8.3.1.8.1 During the final stages of a Category I or APV approach, the receiver shall use only measurement blocks from Type 1 or Type 101 messages that were received within the last 3.5 seconds.

3.6.8.3.1.8.2 The receiver shall use message data from a GBAS ground subsystem for Category I precision approach or APV guidance only if the GCID indicates 1, 2, 3 or 4 prior to initiating the final stages of an approach.

3.6.8.3.1.8.3 The receiver shall ignore any changes in GCID during the final stages of an approach.

3.6.8.3.1.8.4 The receiver shall not provide approach vertical guidance based on a particular FAS data block transmitted in a Type 4 message if the FASVAL received prior to initiating the final stages of the approach is set to "1111 1111".

3.6.8.3.1.8.5 The receiver shall not provide approach guidance based on a particular FAS data block transmitted in a Type 4 message if the FASLAL received prior to initiating the final stages of the approach is set to "1111 1111".

3.6.8.3.1.8.6 Changes in the values of FASLAL and FASVAL data transmitted in a Type 4 message during the final stages of an approach shall be ignored by the receiver.

3.6.8.3.1.8.7 The receiver shall use FAS data only if the FAS CRC for that data has been verified.

3.6.8.3.1.8.8 The receiver shall only use messages for which the GBAS ID (in the message block header) matches the GBAS ID in the header of the Type 4 message which contains the selected FAS data or the Type 2 message which contains the selected RSDS.

3.6.8.3.1.8.9 *Use of FAS data*

3.6.8.3.1.8.9.1 The receiver shall use the Type 4 messages to determine the FAS for precision approach.

3.6.8.3.1.8.9.2 The receiver shall use the Type 4 messages to determine the FAS for APV associated with a channel number between 20 001 and 39 999.

3.6.8.3.1.8.9.3 The receiver shall use the FAS held within the on-board database for APV associated with a channel number between 40 000 and 99 999.

3.6.8.3.1.8.10 When the GBAS ground subsystem does not broadcast the Type 4 message and the selected FAS data are available to the receiver from an airborne database, the receiver shall only use messages from the intended GBAS ground subsystem.

3.6.8.3.1.9 *Conditions for use of data to provide the GBAS positioning service*

3.6.8.3.1.9.1 The receiver shall only use measurement blocks from Type 1 messages that were received within the last 7.5 seconds.

3.6.8.3.1.9.2 The receiver shall only use measurement blocks from Type 101 messages that were received within the last 5 seconds.

3.6.8.3.1.9.3 The receiver shall only use message data if a Type 2 message containing additional data block 1 has been received and the RSDS parameter in this block indicates that the GBAS positioning service is provided.

3.6.8.3.1.9.4 The receiver shall only use messages for which the GBAS ID (in the message block header) matches the GBAS ID in the header of the Type 2 message which contains the selected RSDS.

3.6.8.3.2 *Integrity*

3.6.8.3.2.1 *Bounding of aircraft errors.* For each satellite used in the navigation solution, the receiver shall compute a $\sigma_{receiver}$ such that a normal distribution with zero mean and a standard deviation equal to $\sigma_{receiver}$ bounds the receiver contribution to the corrected pseudo-range error as follows:

$$\int_{y}^{\infty} f(x)\,dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0 \text{ and}$$

$$\int_{-\infty}^{-y} f(x)\,dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0$$

where

f(x) = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}}\,dt.$$

3.6.8.3.2.2 *Use of GBAS integrity parameters*. The aircraft element shall compute and apply the vertical, lateral and horizontal protection levels described in 3.6.5.5 using the GBAS broadcast σ_{pr_gnd}, σ_N, h_0, $\sigma_{vert\_iono\_gradient}$, and B parameters as well as the σ_{pr_air} parameter. If a $B_{i,j}$ parameter is set to the bit pattern "1000 0000" indicating that the measurement is not available, the aircraft element shall assume that $B_{i,j}$ has a value of zero. For Category I precision approach and APV, the aircraft element shall verify that the computed vertical and lateral protection levels are smaller than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

3.6.8.3.3 *Use of satellite ephemeris data*

3.6.8.3.3.1 *IOD check.* The receiver shall only use satellites for which the IOD broadcast by GBAS in the Type 1 or Type 101 message matches the core satellite constellation IOD for the clock and ephemeris data used by the receiver.

3.6.8.3.3.2 *CRC check*. The receiver shall compute the ephemeris CRC for each core satellite constellation's ranging source used in the position solution. The computed CRC shall be validated against the ephemeris CRC broadcast in the Type 1 or Type 101 messages within one second of receiving a new broadcast CRC. The receiver shall immediately cease using any satellite for which the computed and broadcast CRC values fail to match.

Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the broadcast ephemeris CRC for that satellite.

3.6.8.3.3.3 *Ephemeris error position bounds*

3.6.8.3.3.3.1 *Ephemeris error position bounds for Category I precision approach and APV.* If the ground subsystem provides additional data block 1 in the Type 2 messages, the aircraft element shall compute the ephemeris error position bounds defined in 3.6.5.8.1 for each core satellite constellation's ranging source used in the position solution within 1s of receiving the necessary broadcast parameters. The aircraft element shall exclude from the position solution satellites for which the computed vertical or lateral ephemeris error position bounds (VEB_j or LEB_j) are larger than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the necessary broadcast parameters for that satellite to compute the ephemeris error position bounds.

3.6.8.3.3.3.2 *Ephemeris error position bound for the GBAS positioning service*. The aircraft element shall compute and apply the horizontal ephemeris error position bound (HEB_j) defined in 3.6.5.8.2 for each core satellite constellation's ranging source used in the position solution.

3.6.8.3.4 *Message loss*

3.6.8.3.4.1 For Category I precision approach, the receiver shall provide an appropriate alert if no Type 1 or Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.2 For APV, the receiver shall provide an appropriate alert if no Type 1 and no Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.3 For the GBAS positioning service using Type 1 messages, the receiver shall provide an appropriate alert if no Type 1 message was received during the last 7.5 seconds.

3.6.8.3.4.4 For the GBAS positioning service using Type 101 messages, the receiver shall provide an appropriate alert if no Type 101 message was received during the last 5 seconds.

3.6.8.3.5 *Airborne pseudo-range measurements*

3.6.8.3.5.1 *Carrier smoothing for airborne equipment.* Airborne equipment shall utilize the standard 100-second carrier smoothing of code phase measurements defined in 3.6.5.1. During the first 100 seconds after filter start-up, the value of α shall be either:

a) a constant equal to the sample interval divided by 100 seconds; or

b) a variable quantity defined by the sample interval divided by the time in seconds since filter start-up.

3.7 Resistance to interference

3.7.1 PERFORMANCE OBJECTIVES

Note 1.— For unaugmented GPS and GLONASS receivers the resistance to interference is measured with respect to the following performance parameters:

	GPS	*GLONASS*
Tracking error (1 sigma)	*0.4 m*	*0.8 m*

Note 2.— This tracking error neither includes contributions due to signal propagation such as multipath, tropospheric and ionospheric effects nor ephemeris and GPS and GLONASS satellite clock errors.

Note 3.— For SBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.5.8.2.1 and 3.5.8.4.1.

Note 4.— For GBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.6.7.1.1 and 3.6.8.2.1.

Note 5.— The signal levels specified in this section include a minimum standard antenna gain above 5 degree elevation angle of –4.5 dBic. Assumed maximum aircraft antenna gain in the lower hemisphere is –10 dBic. For non-standard antennas with a different minimum gain above 5 degree elevation angle, the signal interference levels can be adjusted accordingly as long as the relative interference-to-signal level is maintained.

Note 6.— The performance requirements are to be met in the interference environments defined below for various phases of flight.

3.7.2 CONTINUOUS WAVE (CW) INTERFERENCE

3.7.2.1 *GPS AND SBAS RECEIVERS*

3.7.2.1.1 GPS and SBAS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-83 and shown in Figure B-15 and with a desired signal level of –164.5 dBW at the antenna port.

3.7.2.1.2 GPS and SBAS receivers used for non-precision approach shall meet the performance objectives with interference thresholds 3 dB less than specified in Table B-83. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the interference thresholds shall be 6 dB less than those specified in Table B-83.

Table B-83. CW interference thresholds for GPS and SBAS receivers

Frequency range f_i of the interference signal	Interference thresholds for receivers used for precision approach phase of flight
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 525 MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 525 MHz < $f_i \leq$ 1 565.42 MHz	Linearly decreasing from –42 dBW to –150.5 dBW
1 565.42 MHz < $f_i \leq$ 1 585.42 MHz	–150.5 dBW
1 585.42 MHz < $f_i \leq$ 1 610 MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq$ 1 618 MHz	Linearly increasing from –60 dBW to –42 dBW*
1 618 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 610 MHz < $f_i \leq$ 1 626.5 MHz	Linearly increasing from –60 dBW to –22 dBW**
1 626.5 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
$f_i >$ 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there is on-board satellite communications.

3.7.2.2 *GLONASS RECEIVERS*

3.7.2.2.1 GLONASS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level of –165.5 dBW at the antenna port.

Table B-84. Interference threshold for GLONASS receivers

Frequency range f_i of the interference signal	Interference thresholds for receivers used for precision approach phase of flight
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 562.15625 MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 562.15625 MHz < $f_i \leq$ 1 583.65625 MHz	Linearly decreasing from –42 dBW to –80 dBW
1 583.65625 MHz < $f_i \leq$ 1 592.9525 MHz	Linearly decreasing from –80 dBW to –149 dBW
1 592.9525 MHz < $f_i \leq$ 1 609.36 MHz	–149 dBW
1 609.36 MHz < $f_i \leq$ 1 613.65625 MHz	Linearly increasing from –149 dBW to –80 dBW
1 613.65625 MHz < $f_i \leq$ 1 635.15625 MHz	Linearly increasing from –80 dBW to –42 dBW*
1 613.65625 MHz < $f_i \leq$ 1 626.15625 MHz	Linearly increasing from –80 dBW to –22 dBW**
1 635.15625 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 626.15625 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
f_i > 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there is on-board satellite communications.

3.7.2.2.2 GLONASS receivers used for non-precision approach shall meet the performance objectives with interference thresholds 3 dB less than specified in Table B-84. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GLONASS signals prior to steady-state navigation, the interference thresholds shall be 6 dB less than those specified in Table B-84.

3.7.3 BAND-LIMITED NOISE-LIKE INTERFERENCE

3.7.3.1 *GPS AND SBAS RECEIVERS*

3.7.3.1.1 After steady-state navigation has been established, GPS and SBAS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 575.42 MHz $\pm Bw_i/2$ and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and Figure B-17 and with the desired signal level of –164.5 dBW at the antenna port.

Note.— Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.1.2 GPS and SBAS receivers used for non-precision approach shall meet their performance objectives with interference thresholds for band-limited noise-like signals 3 dB less than specified in Table B-85. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the interference thresholds for band-limited noise-like signals shall be 6 dB less than those specified in Table B-85.

3.7.3.2 *GLONASS RECEIVERS*

3.7.3.2.1 After steady-state navigation has been established, GLONASS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives while receiving noise-like interfering signals in the frequency band $f_k \pm Bw_i/2$, with power levels at the antenna port equal to the interference thresholds defined in Table B-86 and with a desired signal level of –165.5 dBW at the antenna port.

Note.— f_k is the centre frequency of a GLONASS channel with f_k = 1 602 MHz + k × 0.6525 MHz and k = –7 to + 13 as defined in Table B-16 and Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.2.2 GLONASS receivers used for non-precision approach shall meet their performance objectives with interference thresholds for band-limited noise-like signals 3 dB less than specified in Table B-85. For terminal area and en-route steady-state navigation operations, and for initial acquisition of the GLONASS signals prior to steady-state navigation, the interference thresholds for band-limited noise-like signals shall be 6 dB less than those specified in Table B-86.

Note.— For the approach phase of flight it is assumed that the receiver operates in tracking mode and acquires no new satellites.

3.7.3.3 *Pulsed interference*. After steady-state navigation has been established, the receiver shall meet the performance objectives while receiving pulsed interference signals with characteristics according to Table B-87 where the interference threshold is defined at the antenna port.

3.7.3.4 SBAS and GBAS receivers shall not output misleading information in the presence of interference including interference levels above those specified in 3.7.

Note.— Guidance material on this requirement is given in Attachment D, 10.6.

3.8 GNSS aircraft satellite receiver antenna

3.8.1 *Antenna coverage*. The GNSS antenna shall meet the performance requirements for the reception of GNSS satellite signals from 0 to 360 degrees in azimuth and from 0 to 90 degrees in elevation relative to the horizontal plane of an aircraft in level flight.

3.8.2 *Antenna gain.* The minimum antenna gain shall not be less than that shown in Table B-88 for the specified elevation angle above the horizon. The maximum antenna gain shall not exceed +7 dBic for elevation angles above 5 degrees.

3.8.3 *Polarization*. The GNSS antenna polarization shall be right-hand circular (clockwise with respect to the direction of propagation).

3.9 Cyclic redundancy check

Each CRC shall be calculated as the remainder, R(x), of the Modulo-2 division of two binary polynomials as follows:

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

where

k = the number of bits in the particular CRC;
M(x) = the information field, which consists of the data items to be protected by the particular CRC represented as a polynomial;
G(x) = the generator polynomial specified for the particular CRC;
Q(x) = the quotient of the division; and
R(x) = the remainder of the division, contains the CRC:

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

Table B-85. Interference threshold for band-limited noise-like interference to GPS and SBAS receivers used for precision approach

Interference bandwidth	Interference threshold
0 Hz < Bw_i ≤ 700 Hz	–150.5 dBW
700 Hz < Bw_i ≤ 10 kHz	–150.5 + 6 $\log_{10}$(BW/700) dBW
10 kHz < Bw_i ≤ 100 kHz	–143.5 + 3 $\log_{10}$(BW/10000) dBW
100 kHz < Bw_i ≤ 1 MHz	–140.5 dBW
1 MHz < Bw_i ≤ 20 MHz	Linearly increasing from –140.5 to –127.5 dBW*
20 MHz < Bw_i ≤ 30 MHz	Linearly increasing from –127.5 to –121.1 dBW*
30 MHz < Bw_i ≤ 40 MHz	Linearly increasing from –121.1 to –119.5 dBW*
40 MHz < Bw_i	–119.5 dBW*

* The interference threshold is not to exceed –140.5 dBW/MHz in the frequency range 1 575.42 ±10 MHz.

Table B-86. Interference threshold for band-limited noise-like interference to GLONASS receivers used for precision approach

Interference bandwidth	Interference threshold
0 Hz < Bw_i ≤ 1 kHz	–149 dBW
1 kHz < Bw_i ≤ 10 kHz	Linearly increasing from –149 to –143 dBW
10 kHz < Bw_i ≤ 0.5 MHz	–143 dBW
0.5 MHz < Bw_i ≤ 10 MHz	Linearly increasing from –143 to –130 dBW
10 MHz < Bw_i	–130 dBW

Table B-87. Interference thresholds for pulsed interference

	GPS and SBAS	GLONASS
Frequency range	1 575.42 MHz ± 10 MHz	1 592.9525 MHz to 1 609.36 MHz
Interference threshold (Pulse peak power)	–20 dBW	–20 dBW
Pulse width	≤125 μs	≤250 μs
Pulse duty cycle	≤1%	≤1%

Table B-88. Minimum antenna gain — GPS/SBAS and GLONASS

Elevation angle degrees	Minimum gain dBic
0	–7.5
5	–4.5
10	–3
15 to 90	–2

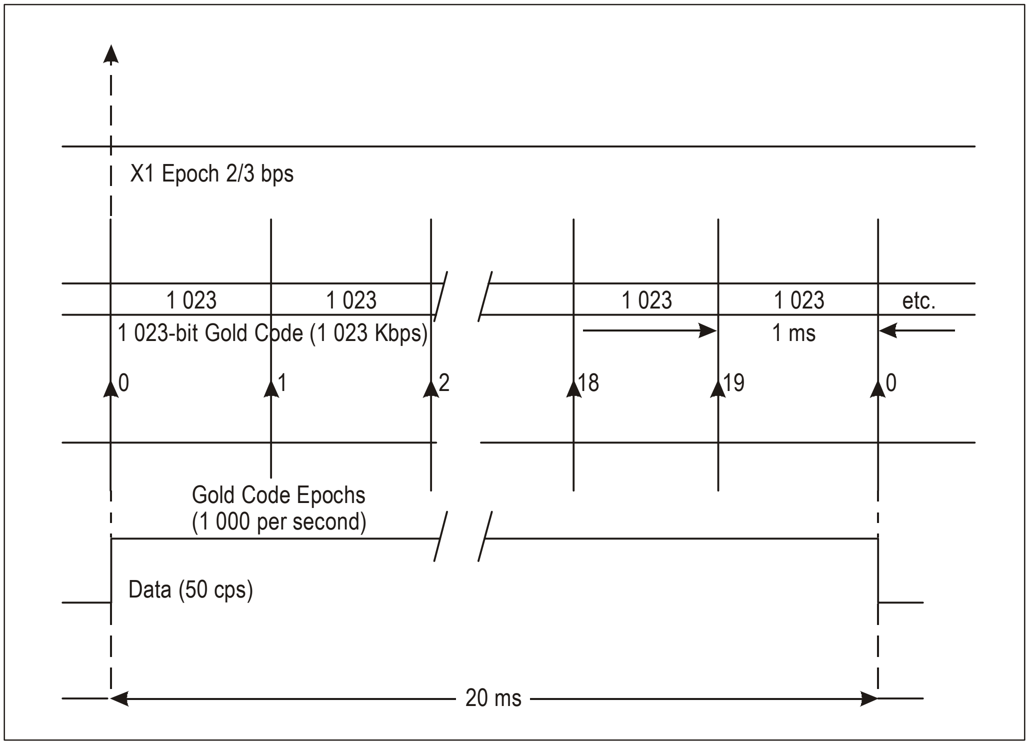


Figure B-1. C/A code timing relationships

SUBFRAME 1	TLM	HOW	GPS week number, SV accuracy and health
SUBFRAME 2	TLM	HOW	Ephemeris parameters
SUBFRAME 3	TLM	HOW	Ephemeris parameters
SUBFRAME 4 (25 pages)	TLM	HOW	Almanac and health for satellites 25–32, special messages, satellite configuration, flags, ionospheric and UTC
SUBFRAME 5 (25 pages)	TLM	HOW	Almanac and health for satellites 1–24 and almanac reference time and GPS week number

Figure B-2. Frame structure

Preamble								Reserved																Parity					
1	0	0	0	1	0	1	1	MSB															LSB						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Figure B-3. TLM word format

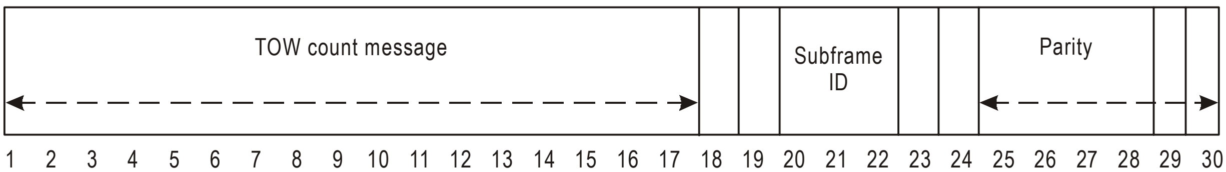
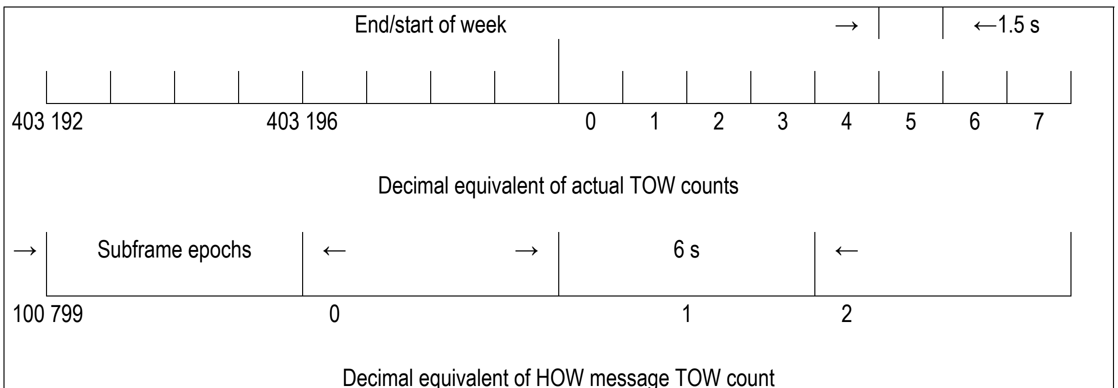
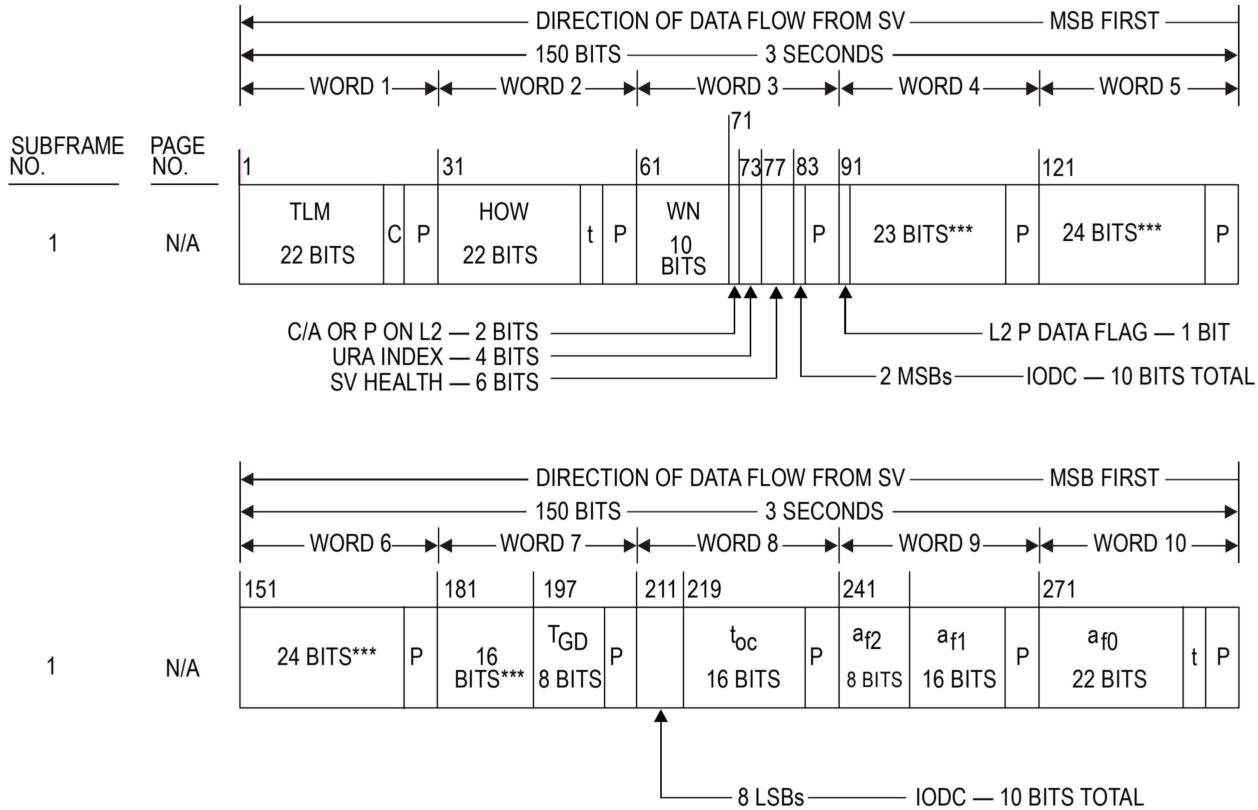


Figure B-4. HOW format



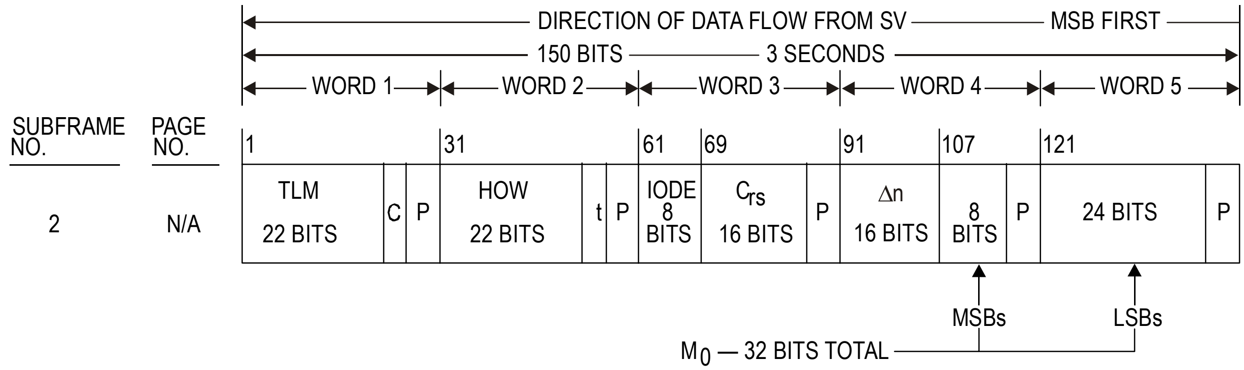
Notes:
1. *To aid in rapid ground lock-on, the HOW of each subframe contains a truncated TOW count.*
2. *The HOW is the second word in each subframe.*
3. *The HOW message TOW count consists of the 17 MSBs of the actual TOW count at the start of the next subframe.*
4. *To convert from the HOW message TOW count to the actual count at the start of the next subframe, multiply by four.*
5. *The first subframe starts synchronously with the end/start of each epoch.*

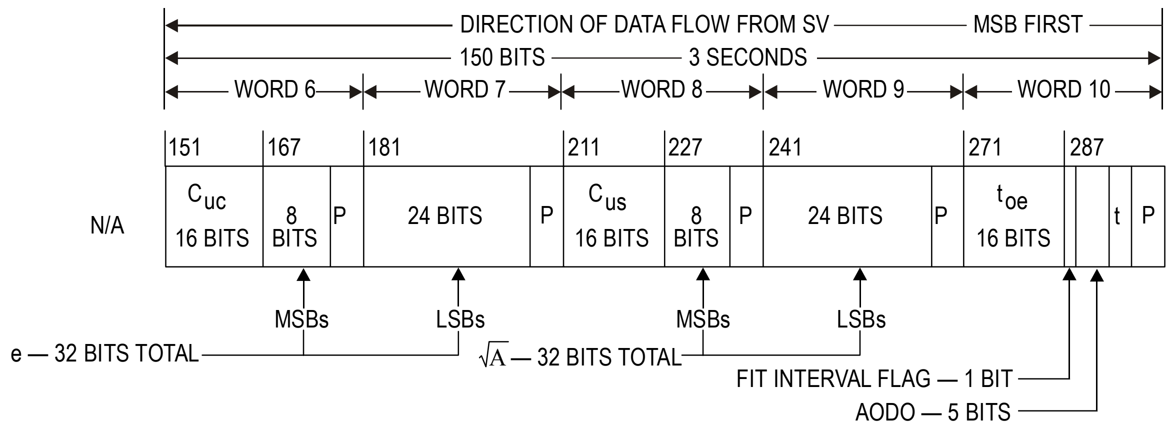
Figure B-5. Time line relationship of HOW



*** RESERVED
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

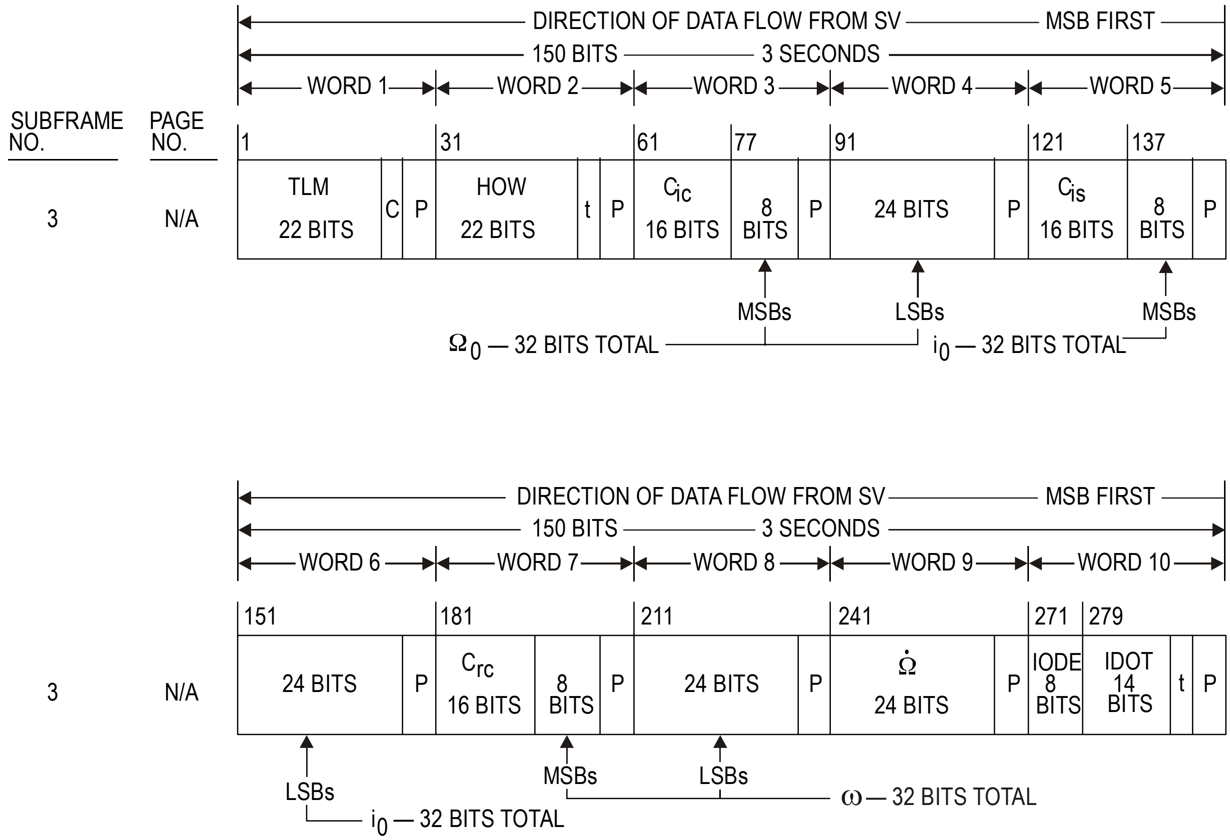
Figure B-6. Data format (1 of 11)





P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (2 of 11)

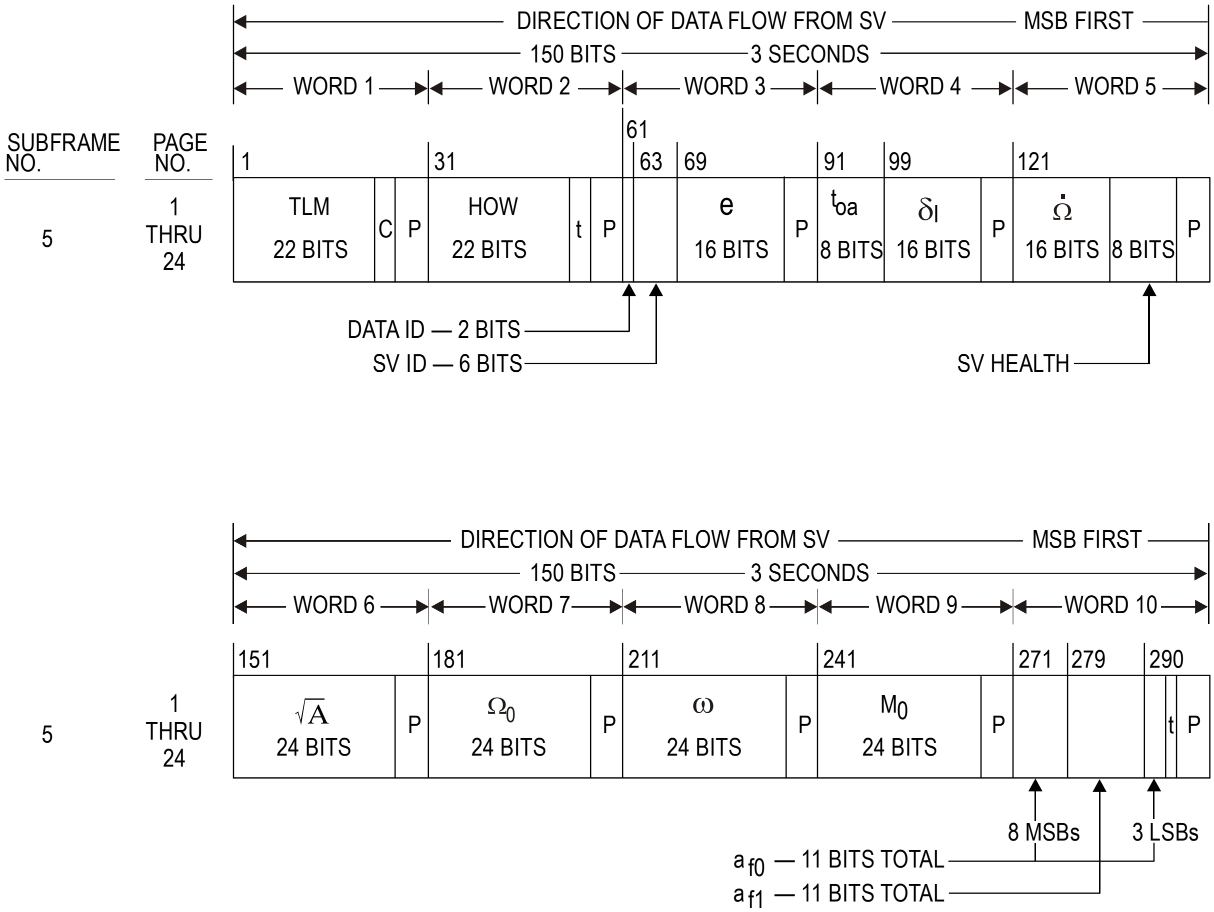


P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

C = TLM BITS 23 AND 24 WHICH ARE RESERVED

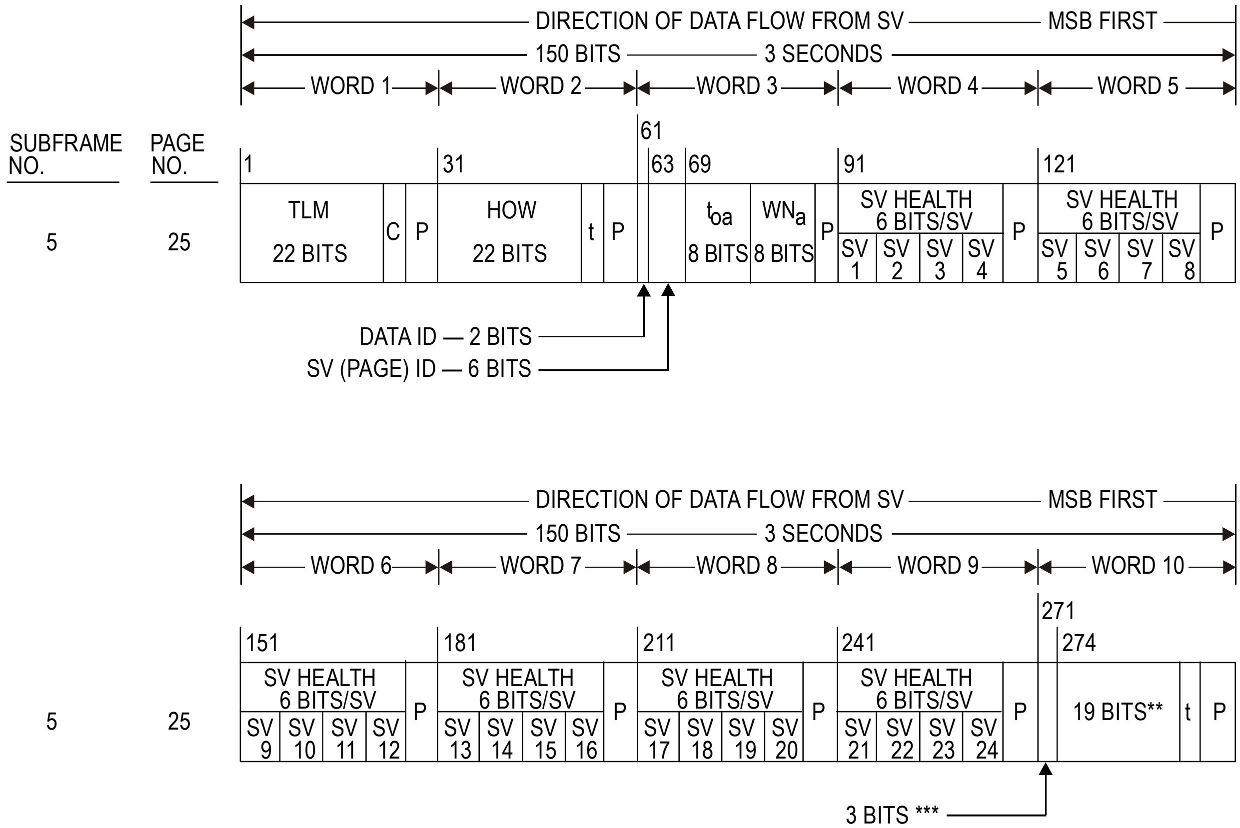
Figure B-6. Data format (3 of 11)



P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Note.— Pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 have the same format as pages 1 through 24 of subframe 5.

Figure B-6. Data format (4 of 11)



** RESERVED FOR SYSTEM USE

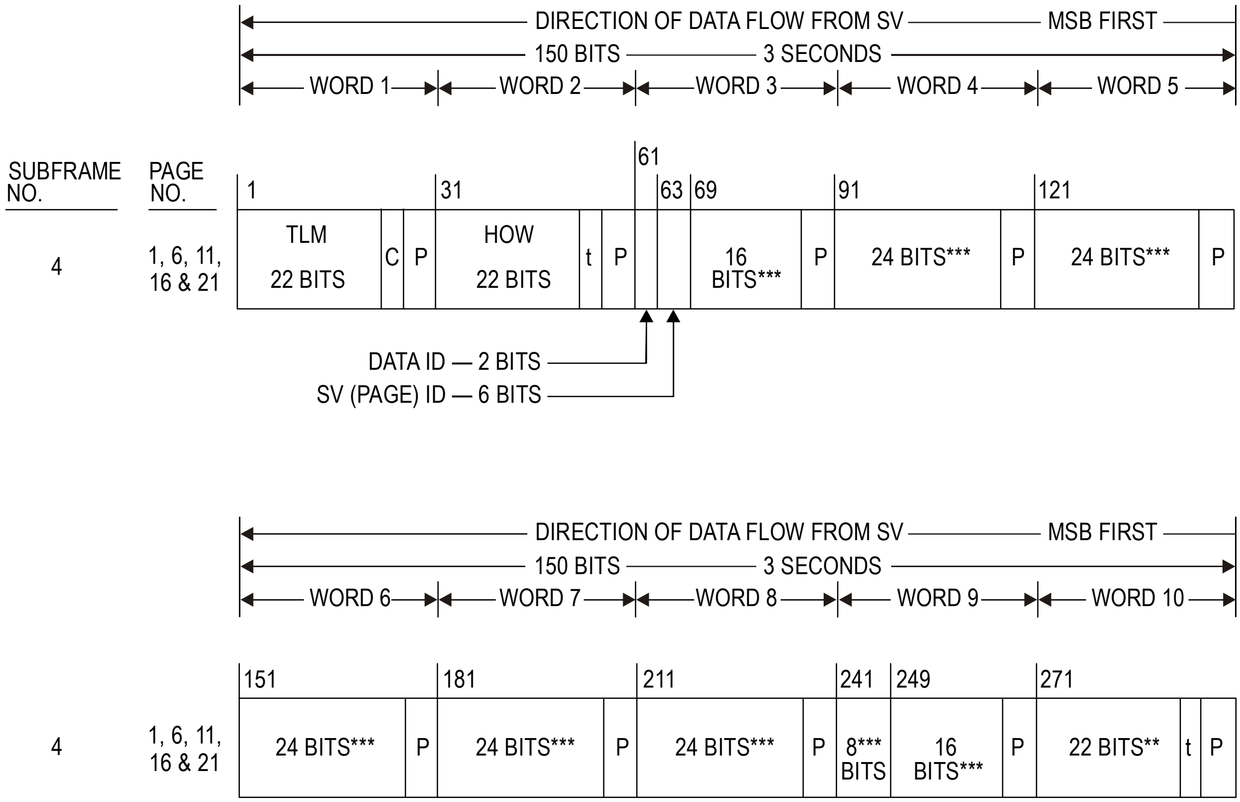
*** RESERVED

P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

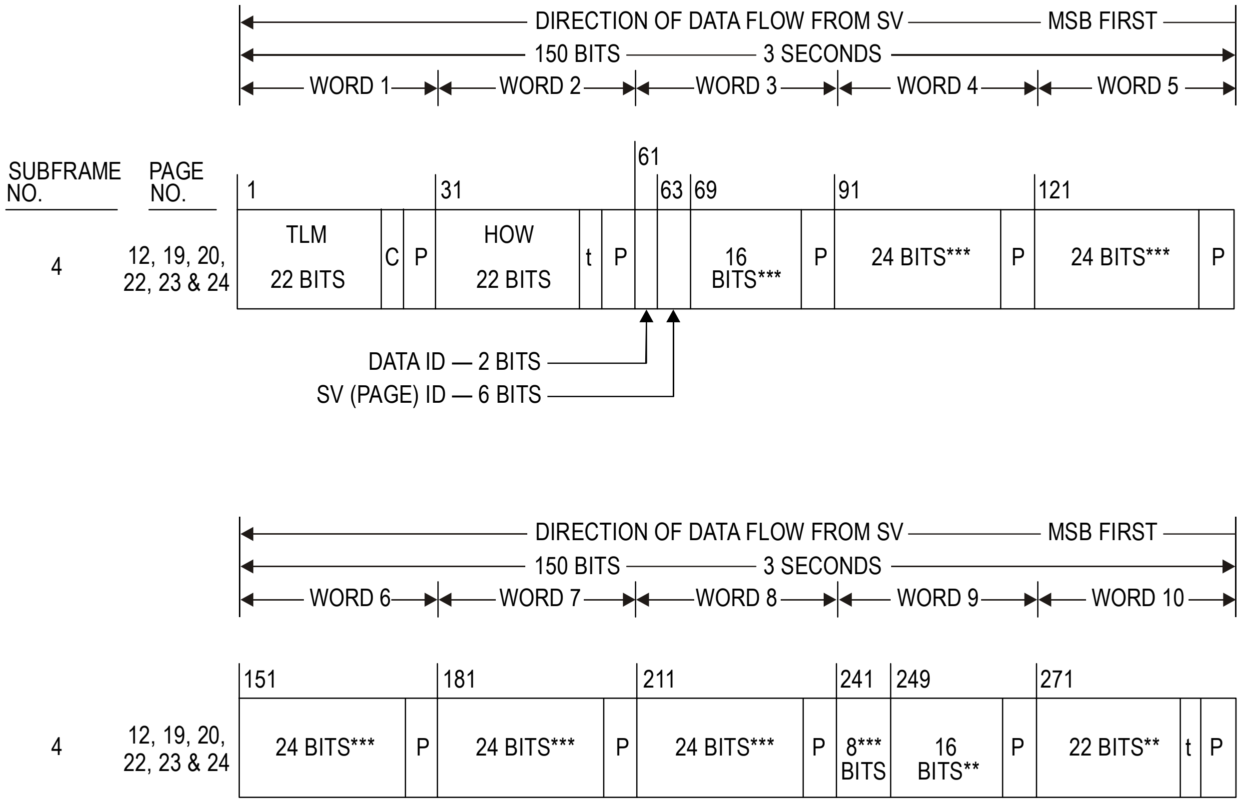
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (5 of 11)



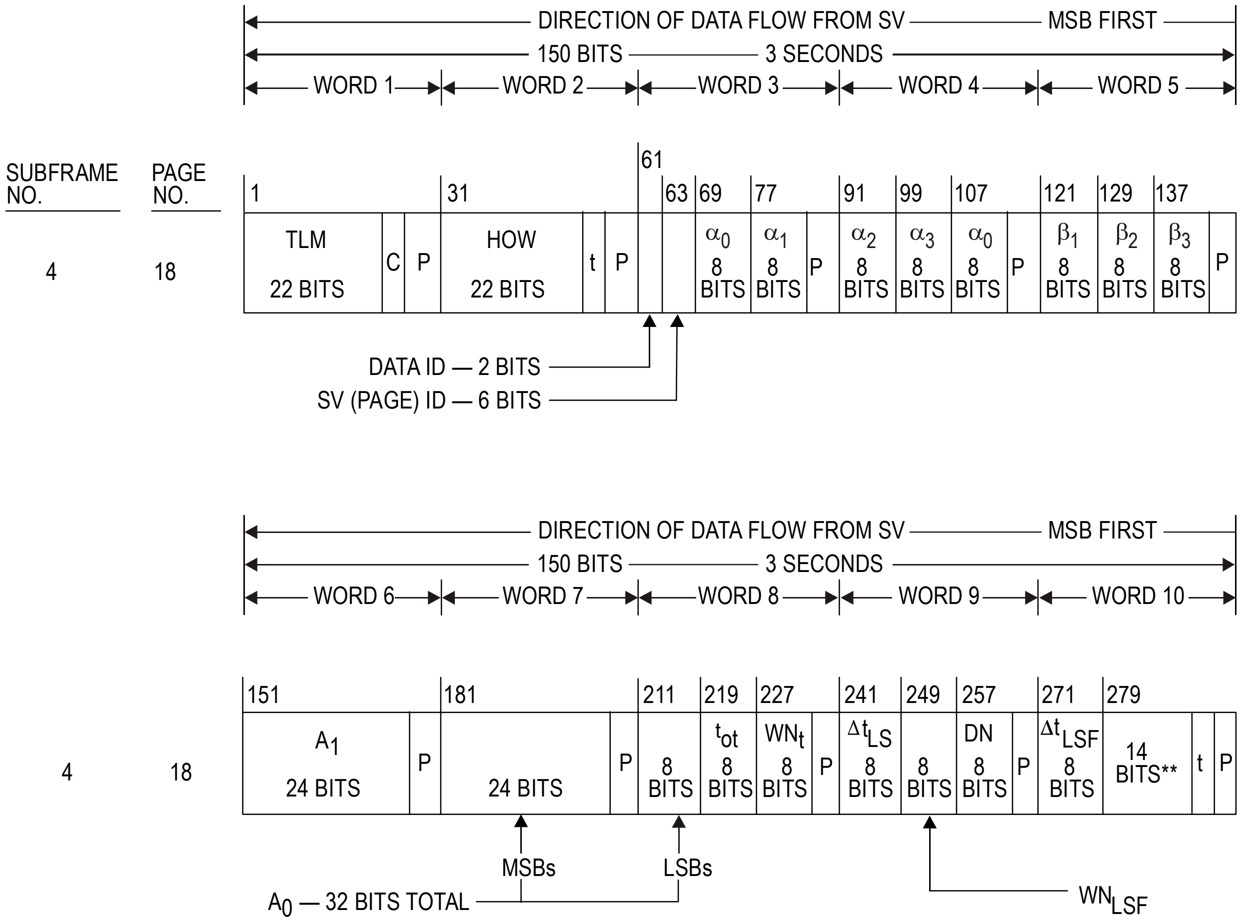
** RESERVED FOR SYSTEM USE
*** RESERVED
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (6 of 11)



** RESERVED FOR SYSTEM USE
*** RESERVED
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (7 of 11)



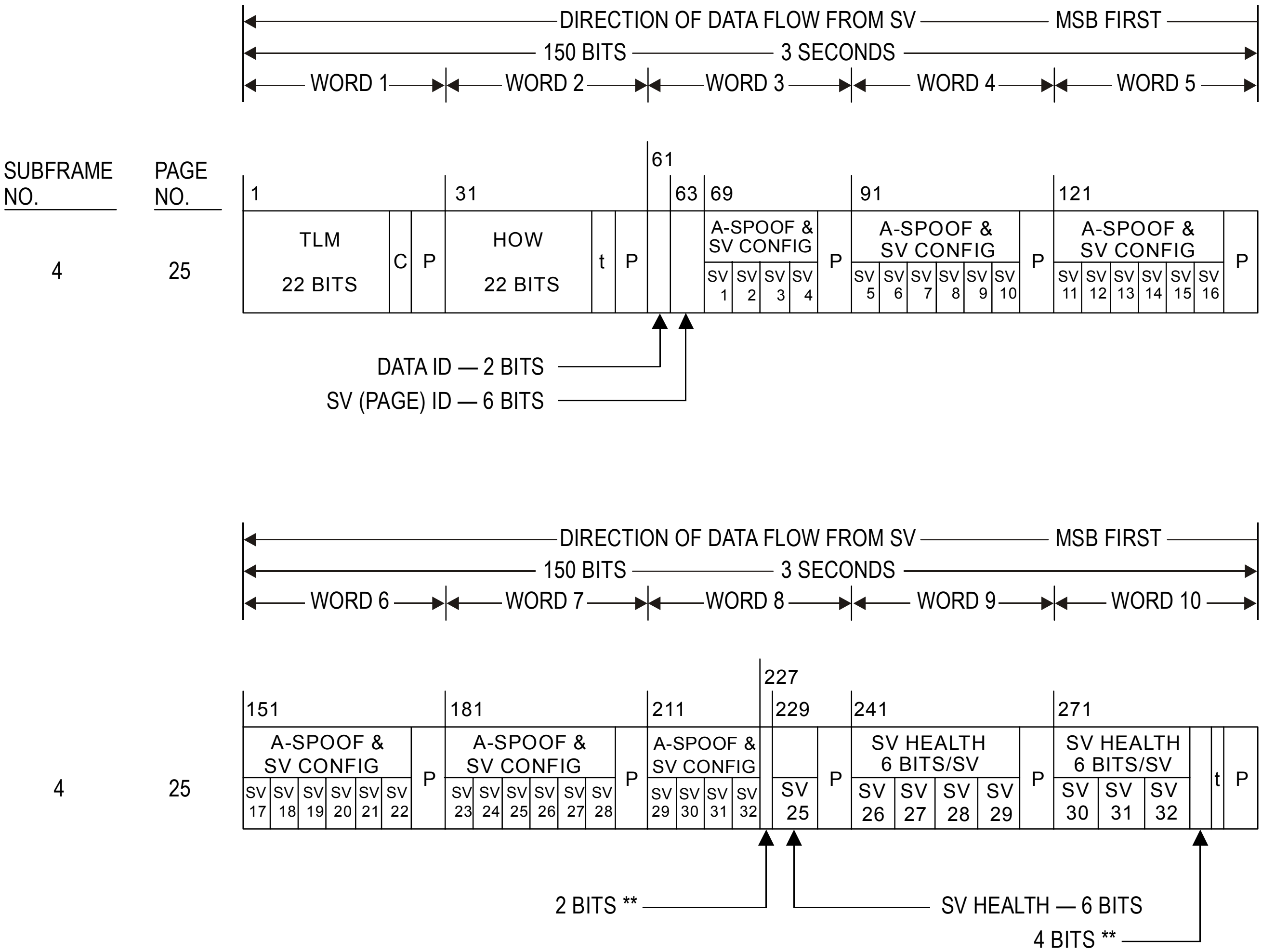
** RESERVED FOR SYSTEM USE

P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

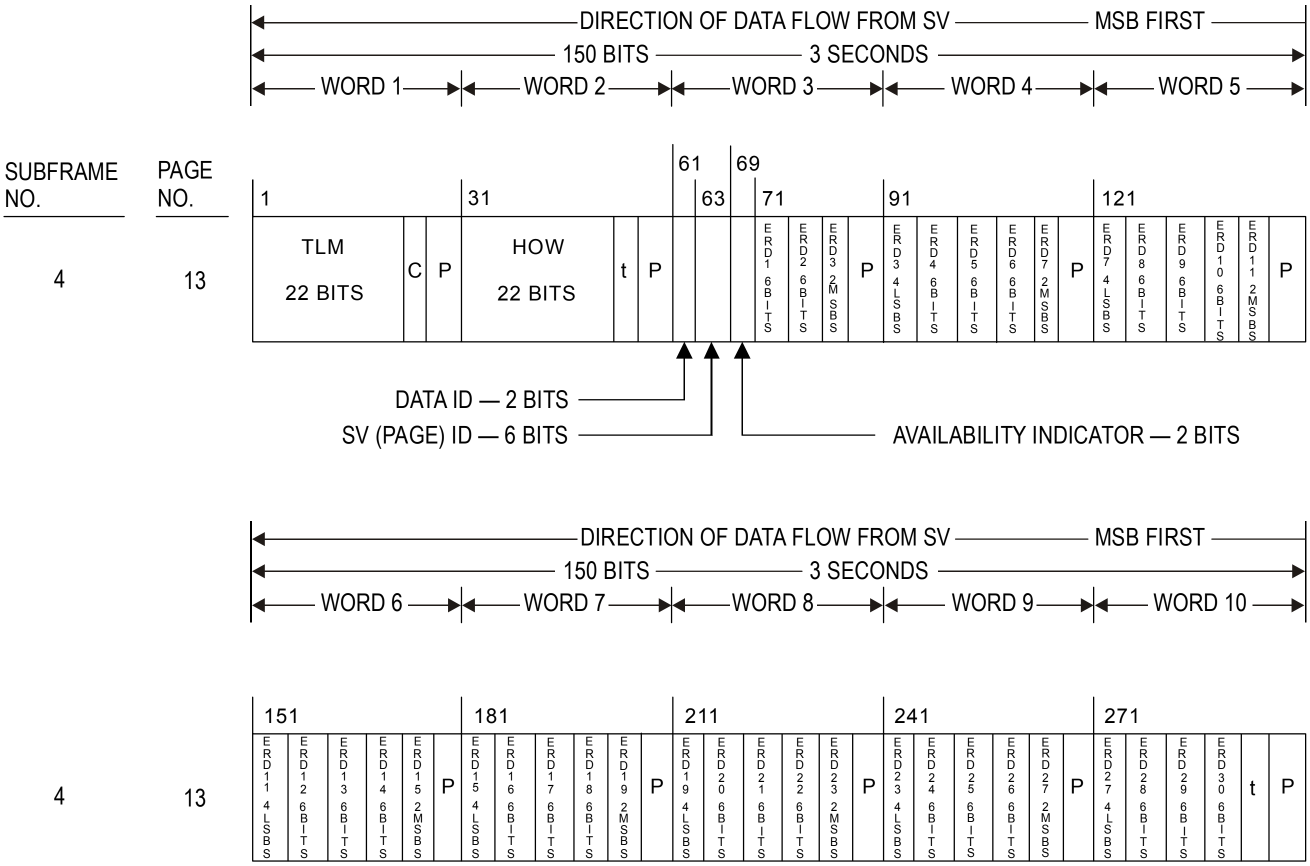
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (8 of 11)



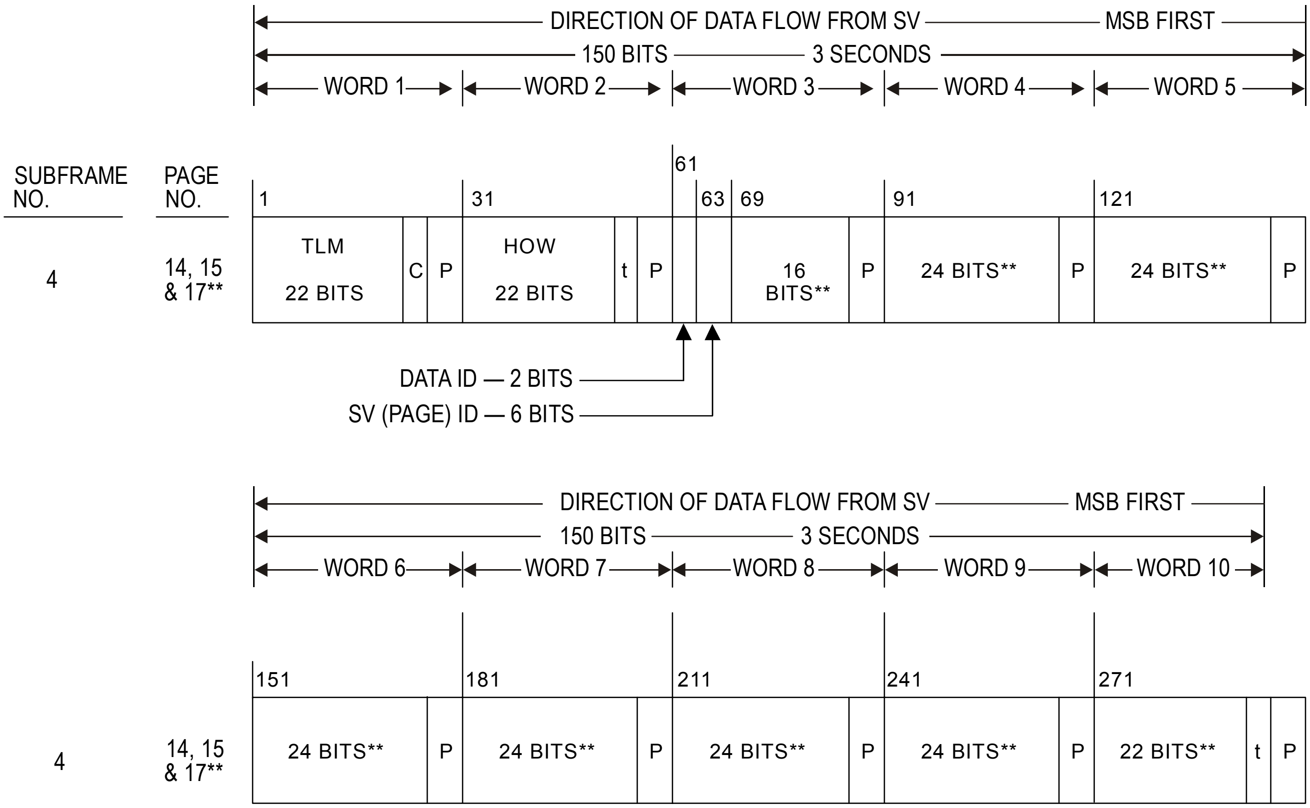
** RESERVED FOR SYSTEM USE
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (9 of 11)



P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (10 of 11)



** THE INDICATED PORTIONS OF WORDS 3 THROUGH 10 OF PAGES 14 AND 15 ARE RESERVED FOR SYSTEM USE, WHILE THOSE OF PAGE 17 ARE RESERVED FOR SPECIAL MESSAGES

P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (11 of 11)

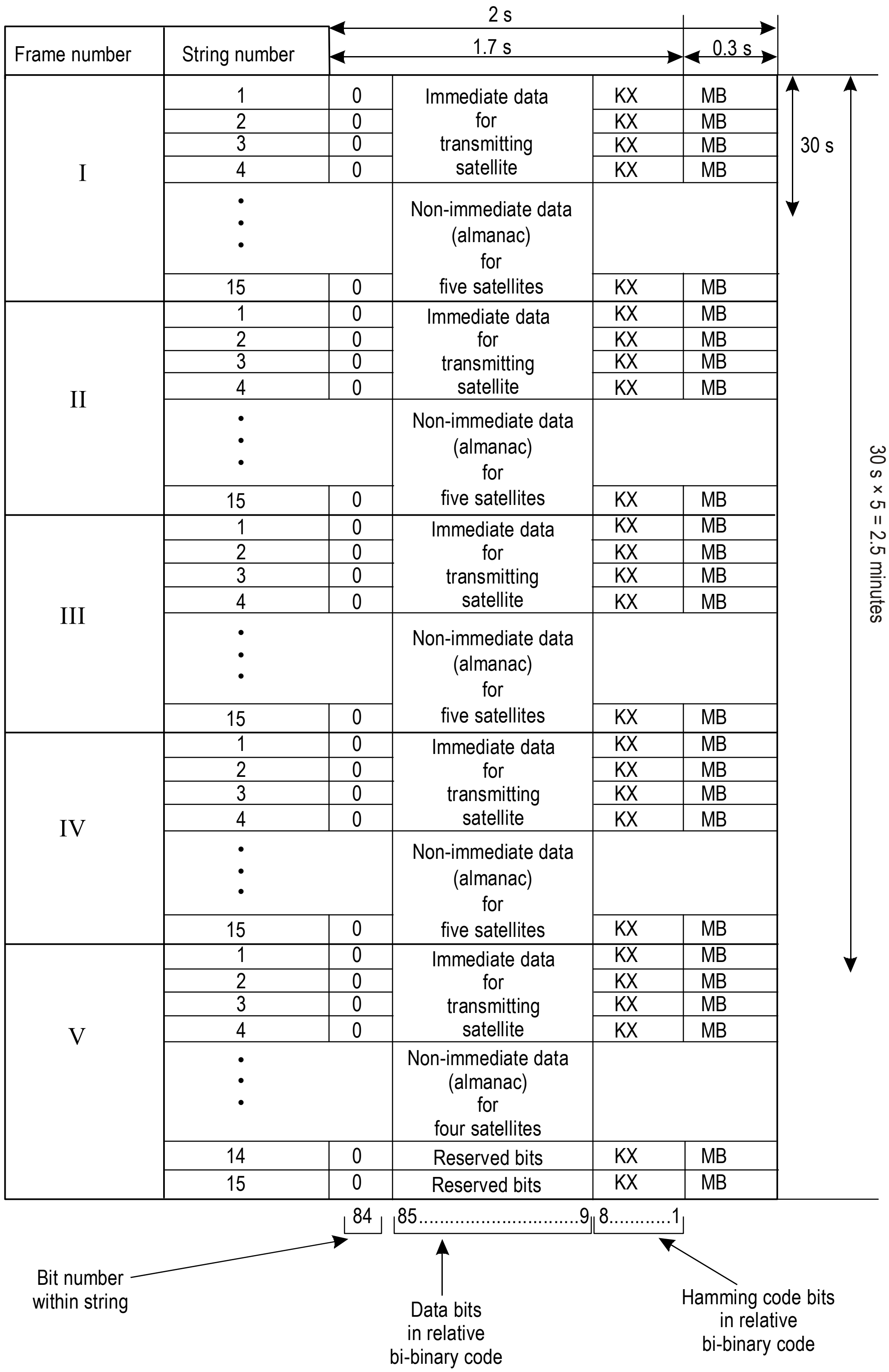
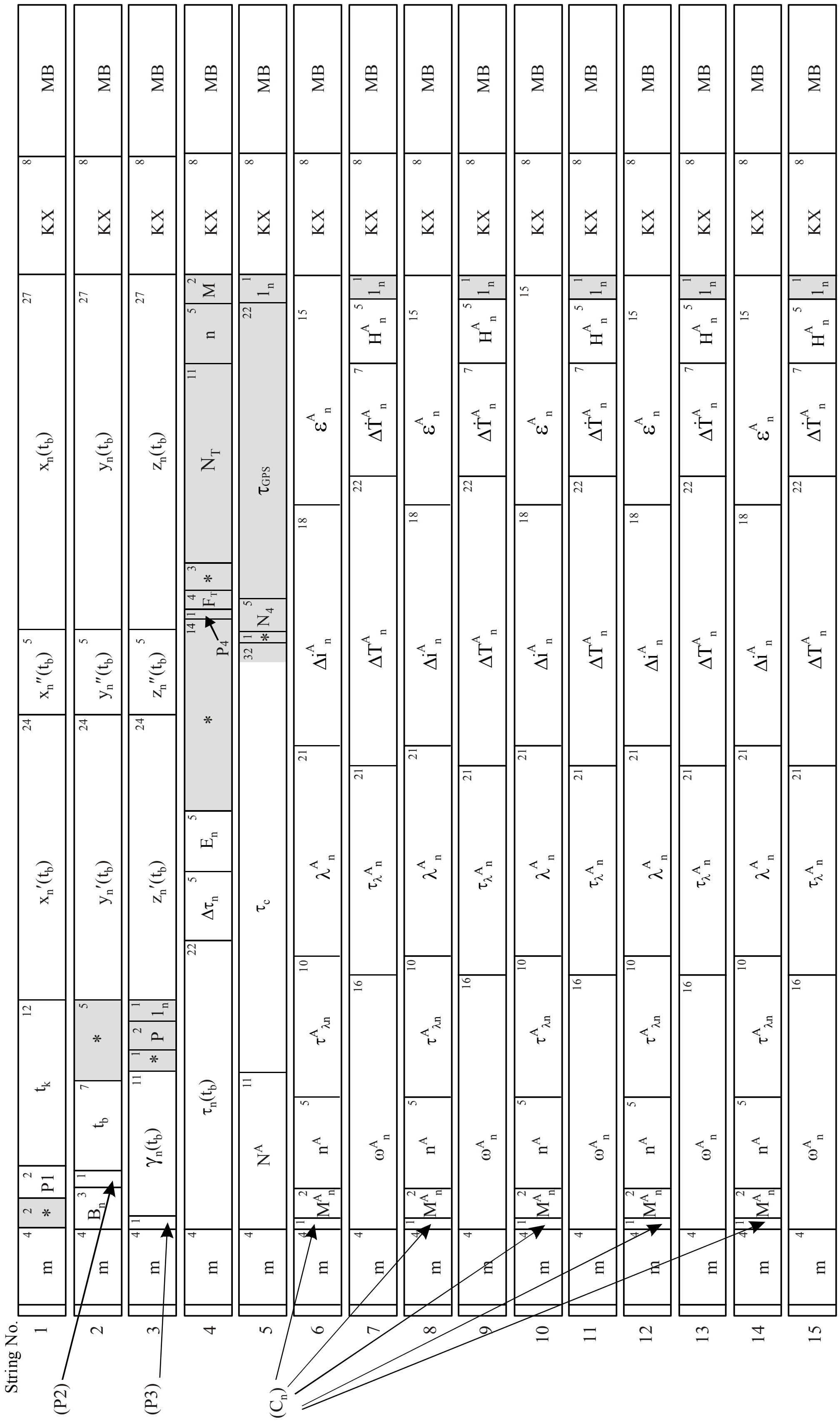


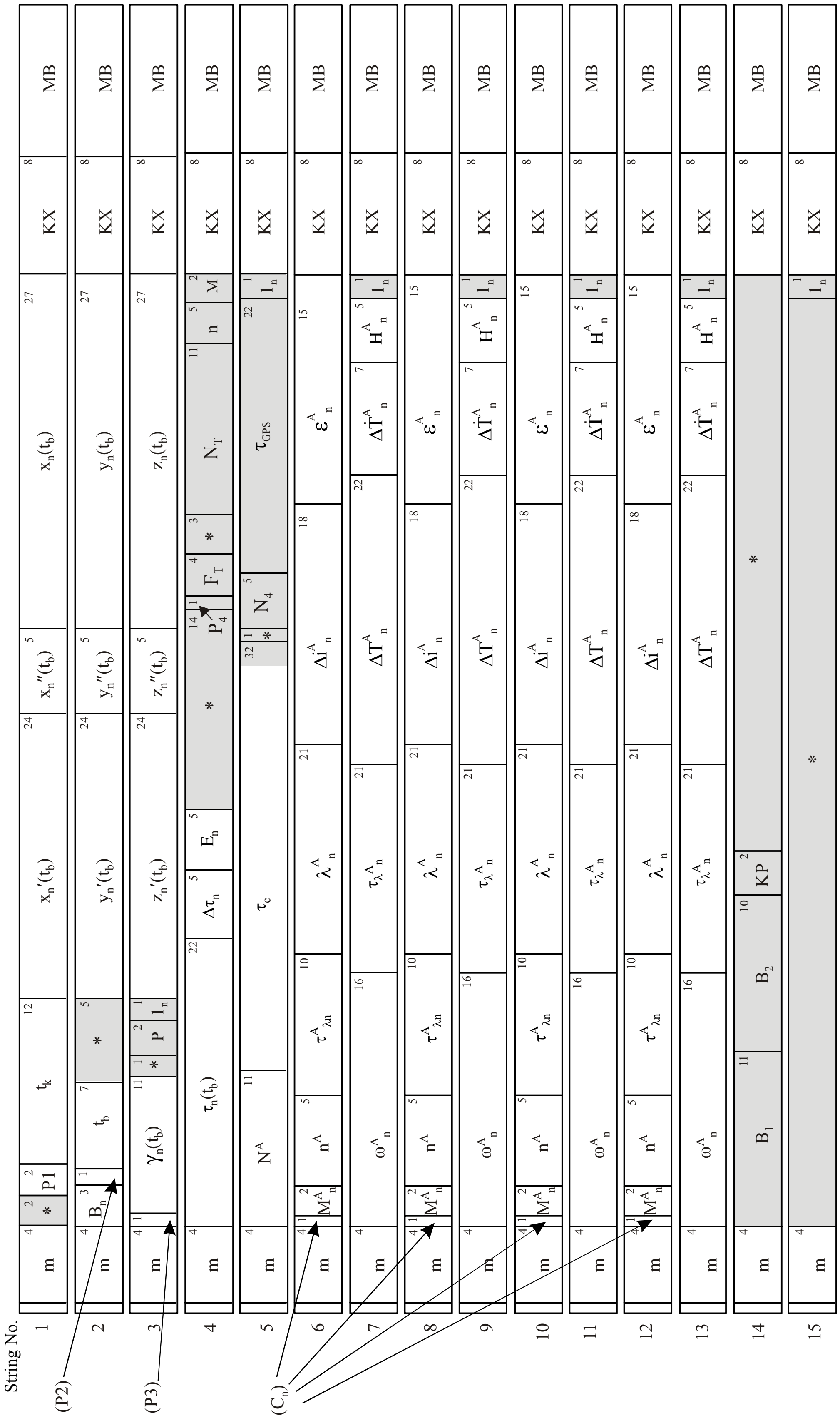
Figure B-7. Superframe structure



* Reserved bits within frame

Note.— Data content, definitions and explanations of parameters are given in 3.2.1.3 and 3.2.1.4. Additional data transmitted by GLONASS-M are highlighted in this figure.

Figure B-8. Frame structure (frames 1 to 4)



* Reserved bits within frame

Note.— Data content, definitions and explanations of parameters are given in 3.2.1.3 and 3.2.1.4. Additional data transmitted by GLONASS-M are highlighted in this figure.

Figure B-9. Frame structure (frame 5)

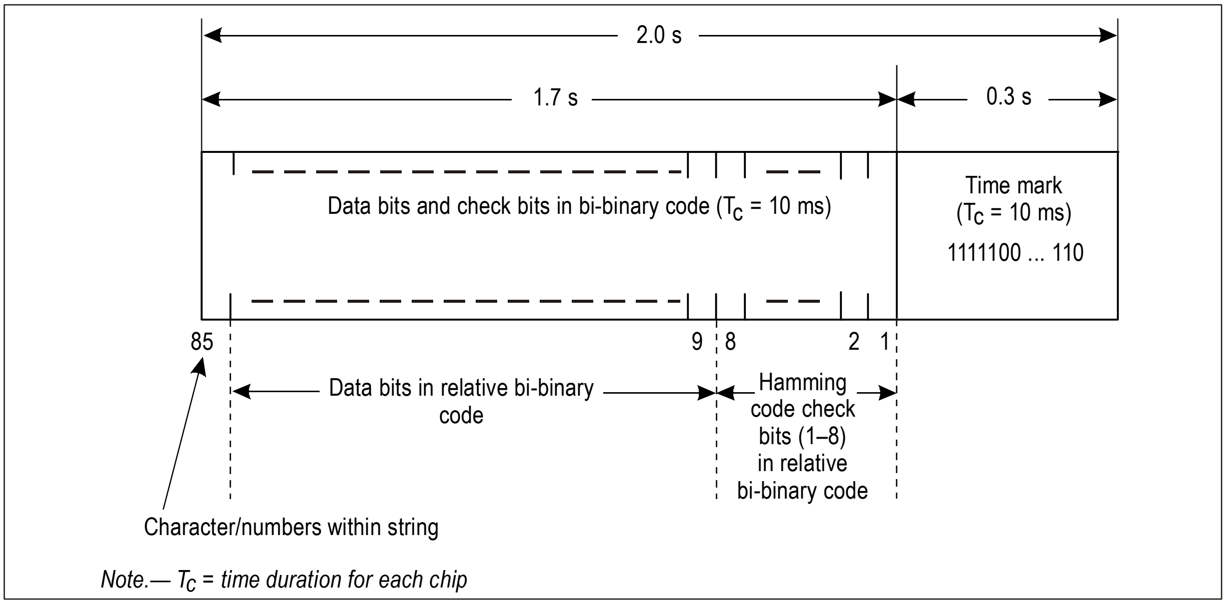


Figure B-10. Data string structure

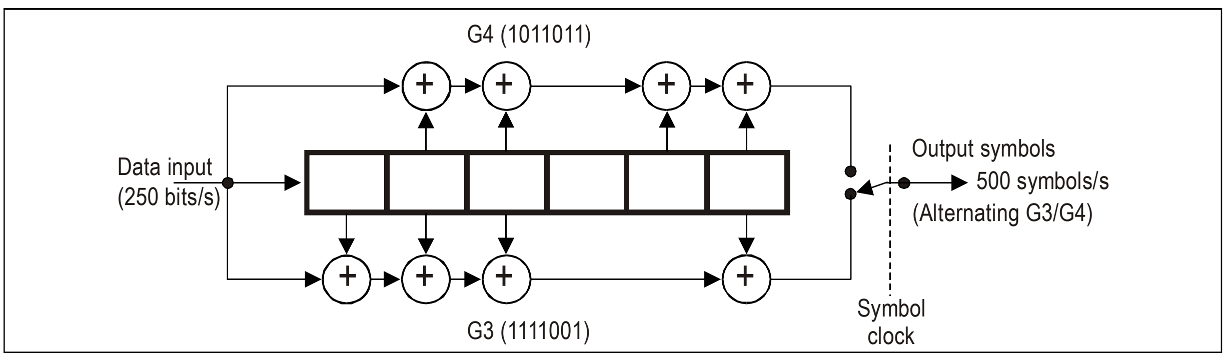


Figure B-11. Convolutional encoding

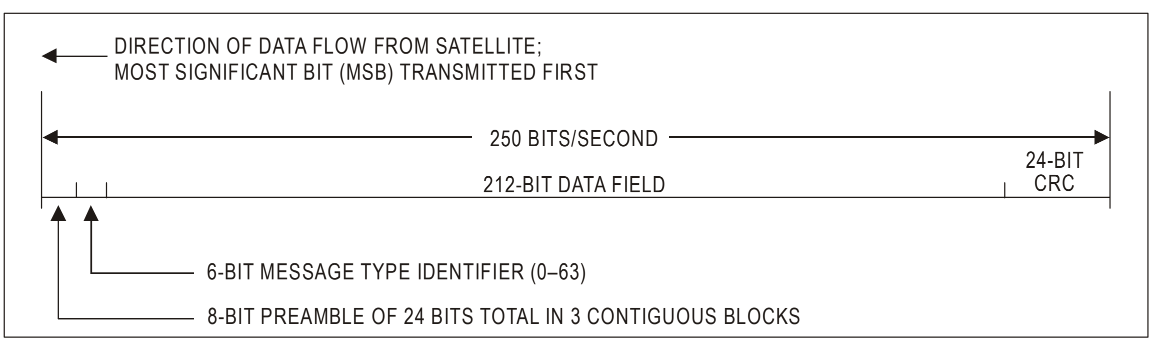


Figure B-12. Data block format

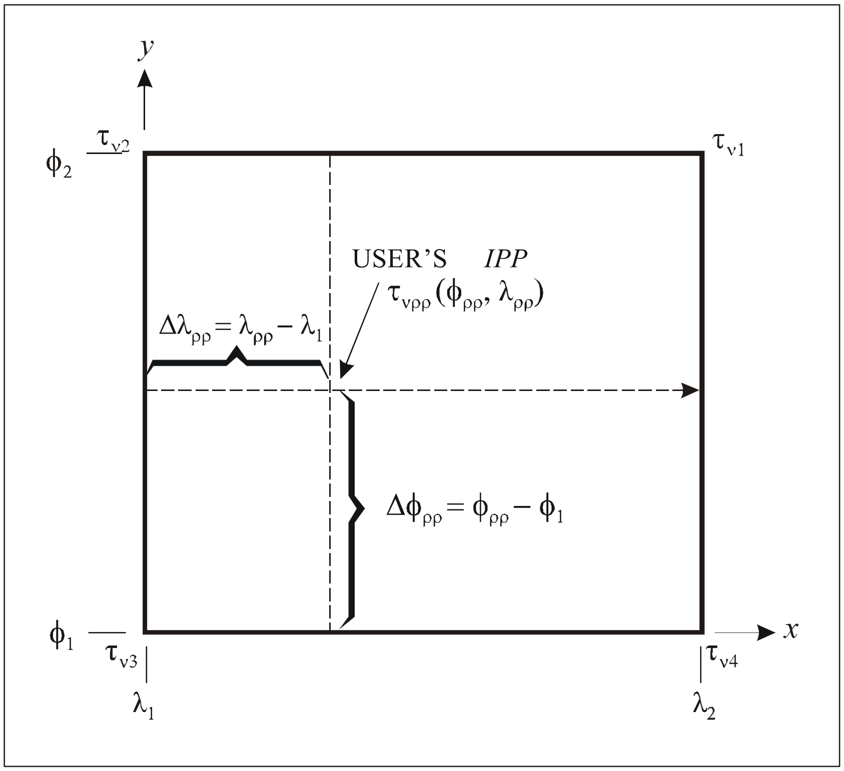


Figure B-13. IGP numbering convention (four IGPs)

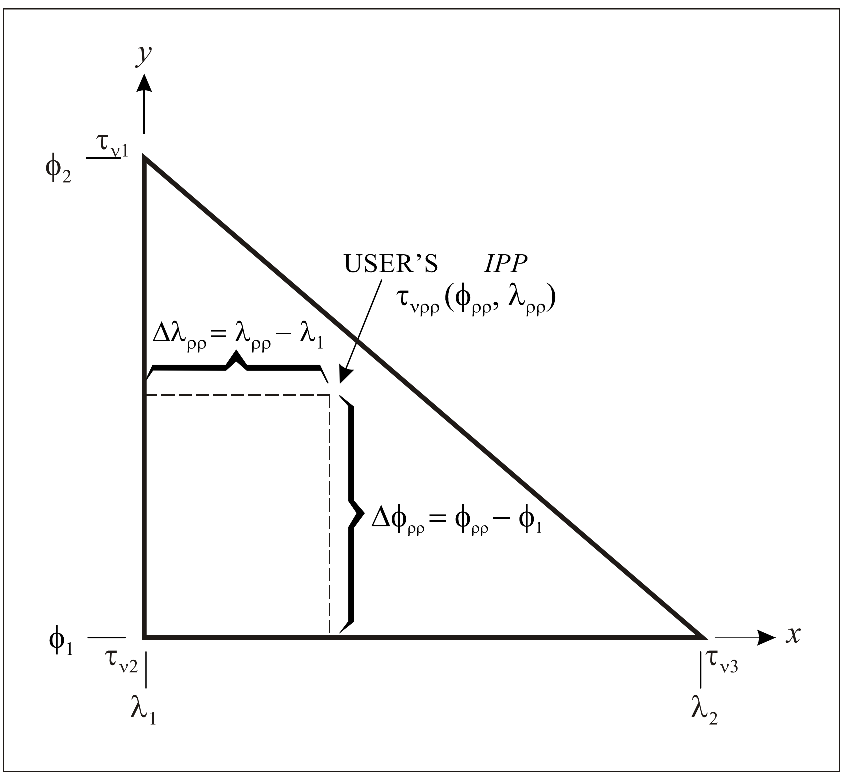


Figure B-14. IGP numbering convention (three IGPs)

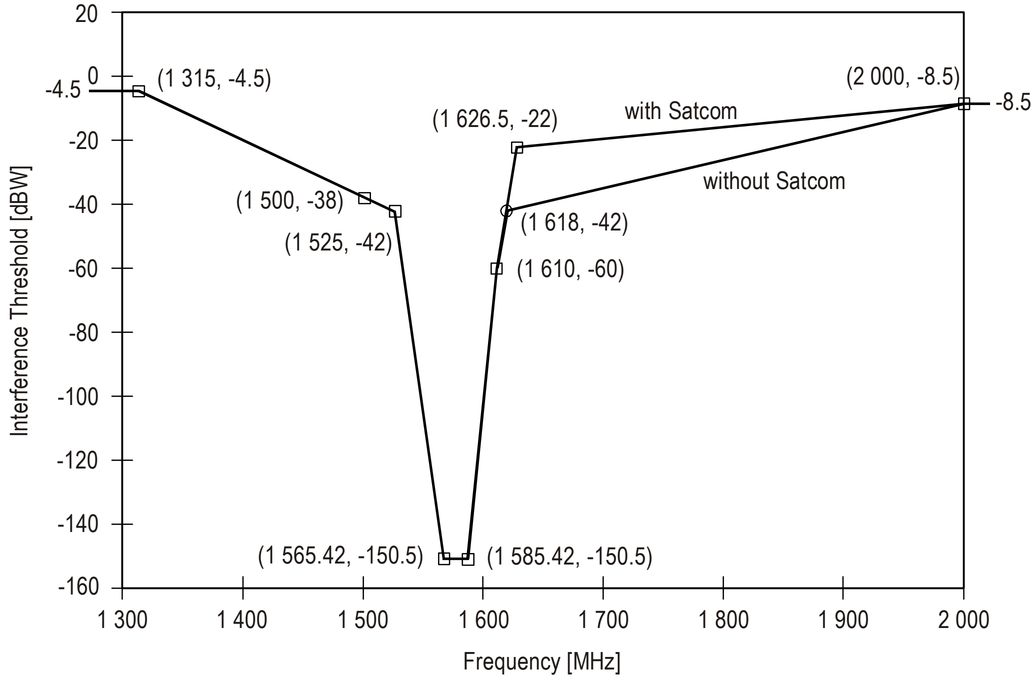


Figure B-15. CW interference thresholds for GPS and SBAS receivers used for precision approach

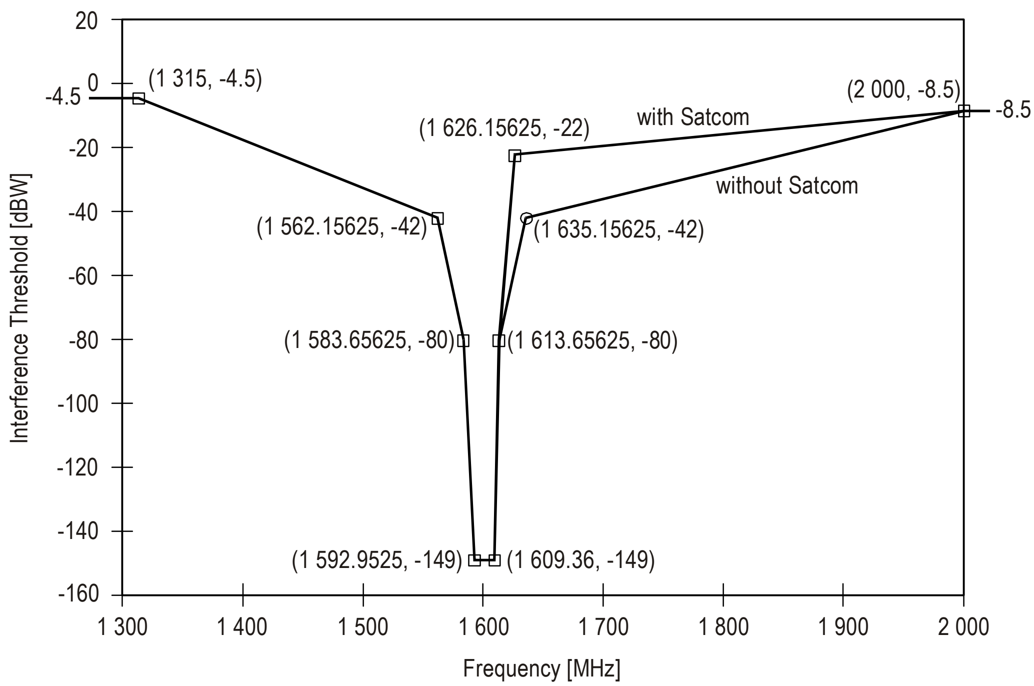


Figure B-16. CW interference thresholds for GLONASS receivers used for precision approach

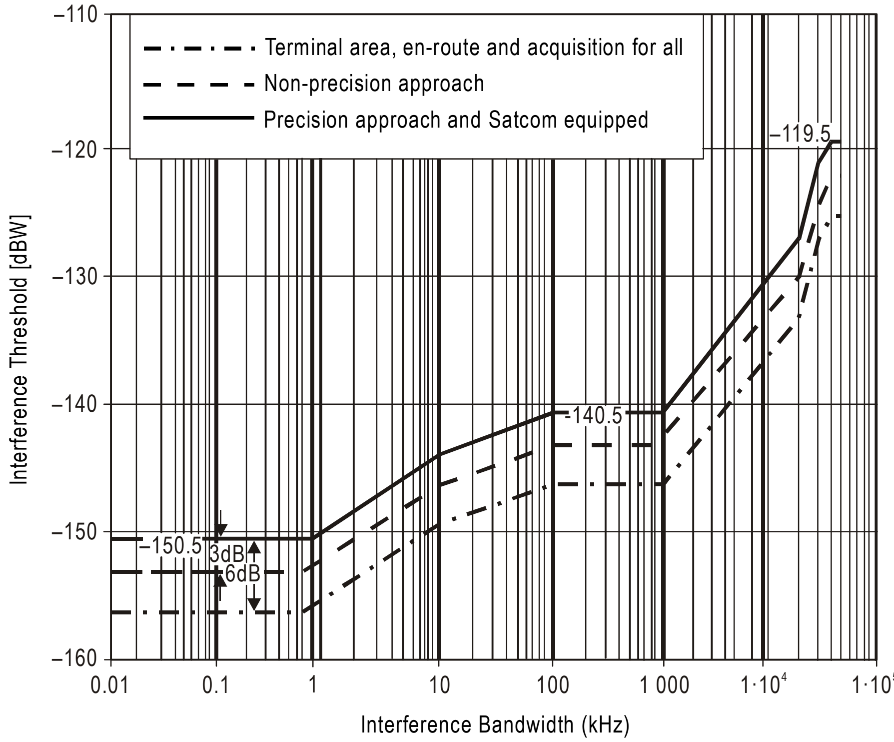


Figure B-17. Interference thresholds versus bandwidth for GPS and SBAS receivers

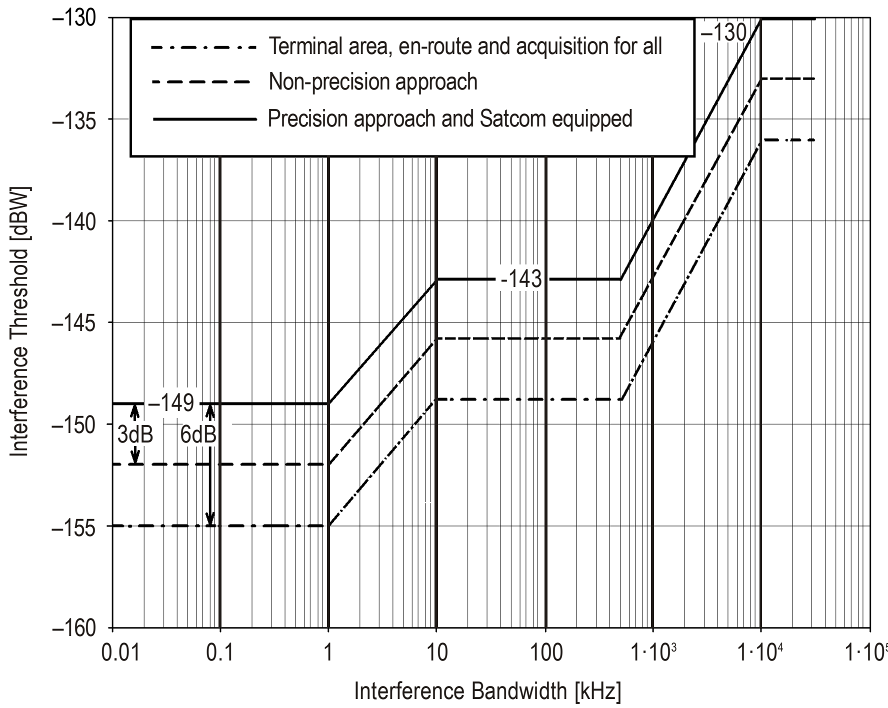


Figure B-18. Interference thresholds versus bandwidth for GLONASS

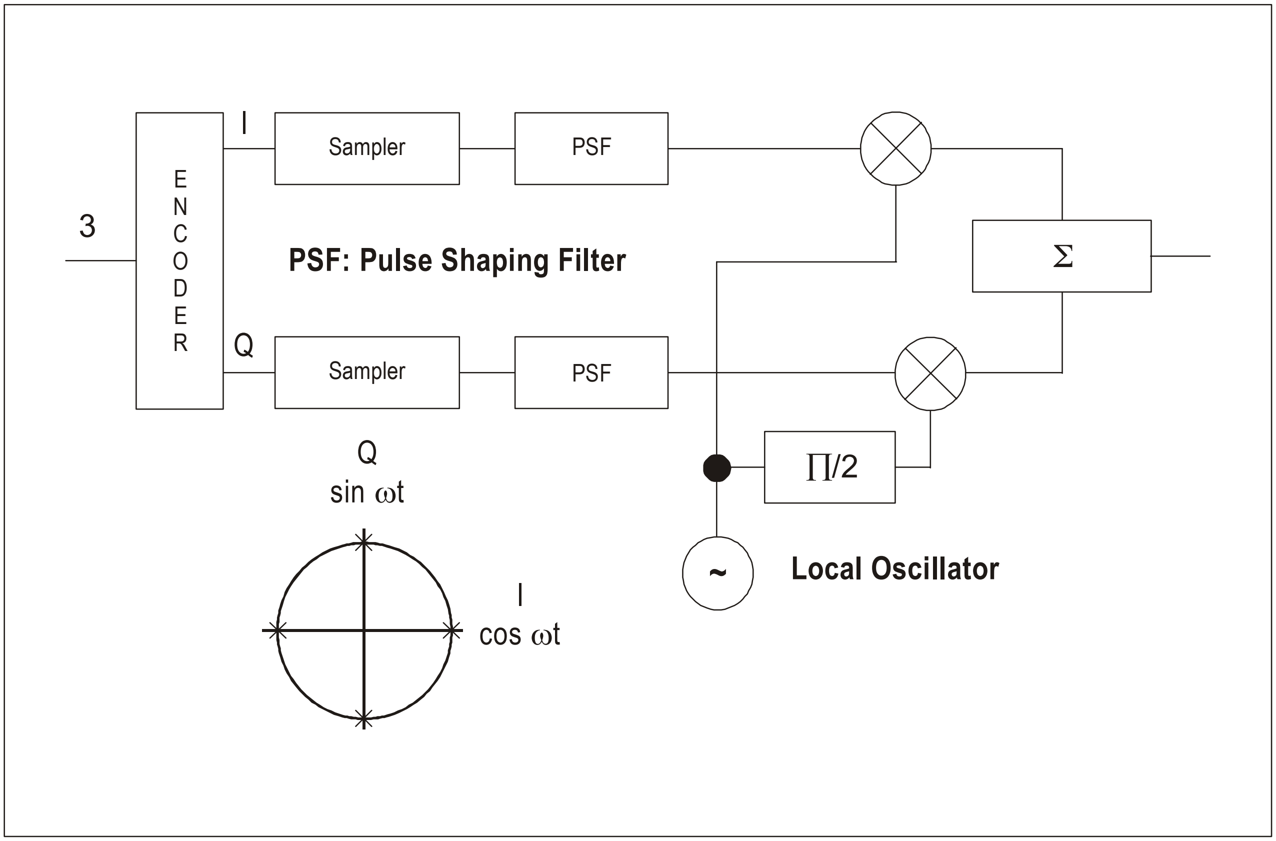


Figure B-19. Example data modulation

ATTACHMENT C. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE STANDARDS AND RECOMMENDED PRACTICES FOR ILS, VOR, PAR, 75 MHz MARKER BEACONS (EN-ROUTE), NDB AND DME

1. Introduction

The material in this Attachment is intended for guidance and clarification purposes and is not to be considered as part of the specifications or as part of the Standards and Recommended Practices contained in Volume I.

For the clarity of understanding of the text that follows and to facilitate the ready exchange of thoughts on closely associated concepts, the following definitions are included.

Definitions relating to the Instrument Landing System (ILS)

Note.— The terms given here are in most cases capable of use either without prefix or in association with the prefix "indicated". Such usages are intended to convey the following meanings:

No prefix: *the achieved characteristics of an element or concept.*

The prefix "indicated": *the achieved characteristics of an element or concept, as indicated on a receiver (i.e. including the errors of the receiving installation).*

Localizer system	ILS glide path system
Indicated course line. The locus of points in any horizontal plane at which the receiver indicator deflection is zero.	
Indicated course sector. A sector in any horizontal plane containing the indicated course line in which the receiver indicator deflection remains within full-scale values.	
Localizer course bend. A course bend is an aberration of the localizer course line with respect to its nominal position.	***ILS glide path bend.*** An ILS glide path bend is an aberration of the ILS glide path with respect to its nominal position.

2. Material concerning ILS installations

2.1 Operational objectives, design and maintenance objectives, and definition of course structure for Facility Performance Categories

2.1.1 The Facility Performance Categories defined in Chapter 3, 3.1.1 have operational objectives as follows:

Category I operation: A precision instrument approach and landing with a decision height not lower than 60 m (200 ft) and with either a visibility not less than 800 m or a runway visual range not less than 550 m.

Category II operation: A precision instrument approach and landing with a decision height lower than 60 m (200 ft) but not lower than 30 m (100 ft), and a runway visual range not less than 300 m.

Category IIIA operation: A precision instrument approach and landing with:

a) a decision height lower than 30 m (100 ft), or no decision height; and

b) a runway visual range not less than 175 m.

Category IIIB operation: A precision instrument approach and landing with:

a) a decision height lower than 15 m (50 ft), or no decision height; and

b) a runway visual range less than 175 m but not less than 50 m.

Category IIIC operation: A precision instrument approach and landing with no decision height and no runway visual range limitations.

2.1.2 *Capabilities.* Relevant to these objectives will be the type of aircraft using the ILS and the capabilities of the aircraft flight guidance system(s). Modern aircraft fitted with equipment of appropriate design are assumed in these objectives. In practice, however, operational capabilities may extend beyond the specific objectives given at 2.1.1.

2.1.2.1 *Equipage for additional objectives.* The availability of fail-passive and fail-operational flight guidance systems in conjunction with an ILS ground system which provides adequate guidance with an appropriate level of continuity of service and integrity for the particular case can permit the attainment of operational objectives which do not coincide with those described at 2.1.1.

2.1.2.2 *Advanced operations.* For modern aircraft fitted with automatic approach and landing systems, the routine use of such systems is being encouraged by aircraft operating agencies in conditions where the progress of the approach can be visually monitored by the flight crew. For example, such operations may be conducted on Facility Performance Category I — ILS where the guidance quality and coverage exceeds basic requirements given at Chapter 3, 3.1.3.4.1 and extends down to the runway.

2.1.2.3 *ILS classification system.* In order to fully exploit the potential benefits of modern aircraft automatic flight control systems, there is a related need for a method of describing ground-based ILS more completely than can be achieved by reference solely to the Facility Performance Category. This is achieved by the ILS classification system using the three designated characters. It provides a description of those performance aspects which are required to be known from an operations viewpoint in order to decide the operational applications which a specific ILS could support.

2.1.2.4 The ILS classification scheme provides a means to make known the additional capabilities that may be available from a particular ILS ground facility, beyond those associated with the facilities defined in Chapter 3, 3.1.1. These

3.2.8.1 For Basic GNSS receivers, the receiver qualification standards require demonstration of user positioning accuracy in the presence of interference and a model of selective availability (SA) to be less than 100 m (95 per cent of time) horizontally and 156 m (95 per cent of time) vertically. The receiver standards do not require that a Basic GNSS receiver applies the ionospheric correction described in Appendix B, 3.1.2.4.

Note.— The term "Basic GNSS receiver" designates the GNSS avionics that at least meet the requirements for a GPS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-208 as amended by United States Federal Aviation Administration (FAA) TSO-C129A, or EUROCAE ED-72A (or equivalent).

3.2.8.2 Since the discontinuation of SA, the representative user positioning accuracy of GPS has been conservatively estimated to be as shown in Table D-0. The numbers provided assume that the worst two satellites of a nominal 24 GPS satellite constellation are out of service. In addition, a 7 m (1 σ) ionospheric delay model error, a 0.25 m (1 σ) residual tropospheric delay error, and a 0.80 m (1 σ) receiver noise error are assumed. After discontinuation of SA (Attachment D, 1.), the dominant pseudo-range error for users of the GPS Standard Positioning Service is the ionospheric error that remains after application of the ionospheric corrections. This error is also highly variable and depends on conditions such as user geomagnetic latitude, level of solar activity (i.e. point of the solar cycle that applies), level of ionospheric activity (i.e. whether there is a magnetic storm, or not), elevation angle of the pseudo-range measurement, season of the year, and time of day. The ionospheric delay model error assumption reflected in Table D-0 is generally conservative; however, conditions can be found under which the assumed 7 m (1 σ) error during solar maximum would be inadequate.

Table D-0. GPS user positioning accuracy

	GPS user positioning accuracy 95% of time, global average
Horizontal position error	33 m (108 ft)
Vertical position error	73 m (240 ft)

3.2.9 SBAS and GBAS receivers will be more accurate, and their accuracy will be characterized in real time by the receiver using standard error models, as described in Chapter 3, 3.5, for SBAS and Chapter 3, 3.6, for GBAS.

Note 1.— The term "SBAS receiver" designates the GNSS avionics that at least meet the requirements for an SBAS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-229C, as amended by United States FAA TSO-C145A/TSO-C146A (or equivalent).

Note 2.— The term "GBAS receiver" designates the GNSS avionics that at least meet the requirements for a GBAS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-253A, as amended by United States FAA TSO-C161 and TSO-C162 (or equivalent).

3.3 Integrity

3.3.1 Integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation (or phase of flight).

3.3.2 To ensure that the position error is acceptable, an alert limit is defined that represents the largest position error allowable for a safe operation. The position error cannot exceed this alert limit without annunciation. This is analogous to ILS in that the system can degrade so that the error is larger than the 95th percentile but within the monitor limit.

3.3.3 The integrity requirement of the navigation system for a single aircraft to support en-route, terminal, initial approach, non-precision approach and departure is assumed to be $1 - 1 \times 10^{-5}$ per hour.

3.3.4 For satellite-based navigation systems, the signal-in-space in the en-route environment simultaneously serves a large number of aircraft over a large area, and the impact of a system integrity failure on the air traffic management system will be greater than with traditional navigation aids. The performance requirements in Chapter 3, Table 3.7.2.4-1, are therefore more demanding.

3.3.5 For APV and precision approach operations, integrity requirements for GNSS signal-in-space requirements of Chapter 3, Table 3.7.2.4-1, were selected to be consistent with ILS requirements.

3.3.6 Alert limits for typical operations are provided in Note 2 to Table 3.7.2.4-1. A range of alert limits is specified for precision approach operations, reflecting potential differences in system design that may affect the operation. In ILS, monitor thresholds for key signal parameters are standardized, and the monitors themselves have very low measurement noise on the parameter that is being monitored. With differential GNSS, some system monitors have comparably large measurement noise uncertainty whose impact must be considered on the intended operation. In all cases, the effect of the alert limit is to restrict the satellite-user geometry to one where the monitor performance (typically in the pseudorange domain) is acceptable when translated into the position domain.

3.3.7 The smallest precision approach vertical alert limit (VAL) value (10 m (33 ft)) was derived based on the monitor performance of ILS as it could affect the glide slope at a nominal decision altitude of 60 m (200 ft) above the runway threshold. By applying this alert limit, the GNSS error, under faulted conditions, can be directly compared to an ILS error under faulted conditions, such that the GNSS errors are less than or equal to the ILS errors. For those faulted conditions with comparably large measurement noise in GNSS, this results in monitor thresholds are more stringent than ILS.

3.3.8 The largest precision approach VAL value (35 m (115 ft)) was derived to ensure obstacle clearance equivalent to ILS for those error conditions which can be modelled as a bias during the final approach, taking into account that the aircraft decision altitude is independently derived from barometric pressure. An assessment has been conducted of the worst-case effect of a latent bias error equal to the alert limit of 35 m (115 ft), concluding that adequate obstacle clearance protection is provided on the approach and missed approach (considering the decision altitude would be reached early or late, using an independent barometric altimeter). It is important to recognize that this assessment only addressed obstacle clearance and is limited to those error conditions which can be modelled as bias errors. Analysis has shown 35 m (115 ft) bias high and low conditions can be tolerated up to the approach speed category (Categories A through D) glide path angle limits in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS, Doc 8168) without impinging on the ILS obstacle clearance surfaces.

3.3.9 Since the analysis of a 35 m (115 ft) VAL is limited in scope, a system-level safety analysis should be completed before using any value greater than 10 m (33 ft) for a specific system design. The safety analysis should consider obstacle clearance criteria and risk of collision due to navigation error, and the risk of unsafe landing due to navigation error, given the system design characteristics and operational environment (such as the type of aircraft conducting the approach and the supporting airport infrastructure). With respect to the collision risk, it is sufficient to confirm that the assumptions identified in 3.3.8 are valid for the use of a 35 m (115 ft) VAL. With respect to an unsafe landing, the principal mitigation for a navigation error is pilot intervention during the visual segment. Limited operational trials, in conjunction with operational expertise, have indicated that navigation errors of less than 15 m (50 ft) consistently result in acceptable touchdown performance. For errors larger than 15 m (50 ft), there can be a significant increase in the flight crew workload and potentially a significant reduction in the safety margin, particularly for errors that shift the point where the aircraft reaches the decision altitude closer to the runway threshold where the flight crew may attempt to land with an unusually high rate of descent. The hazard severity of this event is major (see the *Safety Management Manual (SMM)* (Doc 9859)). One acceptable means to manage the risks in the visual segment is for the system to comply with the following criteria:

a) the fault-free accuracy is equivalent to ILS. This includes system 95 per cent vertical navigation system error (NSE) less than 4 m (13 ft), and a fault-free system vertical NSE exceeding 10 m (33 ft) with a probability less than 10^{-7} for at the start of the operation. The occurrence of navigation system alerts, either due to rare fault-free performance or to failures, constitute continuity failures. Since the durations of these operations are variable, the continuity requirement is specified as a probability on a per-hour basis.

3.4.2.2 The navigation system continuity requirement for a single aircraft is $1 - 1 \times 10^{-4}$ per hour. However, for satellite-based systems, the signal-in-space may serve a large number of aircraft over a large area. The continuity requirements in Chapter 3, Table 3.7.2.4-1, represent reliability requirements for the GNSS signal-in-space, i.e. they derive mean time between outage (MTBO) requirements for the GNSS elements.

3.4.2.3 A range of values is given in Chapter 3, Table 3.7.2.4-1, for the signal-in-space continuity requirement for en-route operations. The lower value is the minimum continuity for which a system is considered to be practical. It is appropriate for areas with low traffic density and airspace complexity. In such areas, the impact of a navigation system failure is limited to a small number of aircraft, and there is, therefore, no need to increase the continuity requirement significantly beyond the single aircraft requirement ($1 - 1 \times 10^{-4}$ per hour). The highest value given (i.e. $1 - 1 \times 10^{-8}$ per hour) is suitable for areas with high traffic density and airspace complexity, where a failure will affect a large number of aircraft. This value is appropriate for navigation systems where there is a high degree of reliance on the system for navigation and possibly for dependent surveillance. The value is sufficiently high for the scenario based on a low probability of a system failure during the life of the system. Intermediate values of continuity (e.g. $1 - 1 \times 10^{-6}$ per hour) are considered to be appropriate for areas of high traffic density and complexity where there is a high degree of reliance on the navigation system but in which mitigation for navigation system failures is possible. Such mitigation may be through the use of alternative navigation means or the use of ATC surveillance and intervention to maintain separation standards. The values of continuity performance are determined by airspace needs to support navigation where GNSS has either replaced the existing navigation aid infrastructure or where no infrastructure previously existed.

3.4.3 *Approach and landing*

3.4.3.1 For approach and landing operations, continuity of service relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity during the approach and landing, given that it was available at the start of the operation. In particular, this means that loss of continuity events that can be predicted and for which NOTAMs have been issued do not have to be taken into account when establishing compliance of a given system design against the SARPs continuity requirement. The occurrence of navigation system alerts, either due to rare fault-free performance or to failures, constitutes a loss of continuity event. In this case, the continuity requirement is stated as a probability for a short exposure time.

3.4.3.2 The continuity requirements for approach and landing operations represent only the allocation of the requirement between the aircraft receiver and the non-aircraft elements of the system. In this case, no increase in the requirement is considered necessary to deal with multiple aircraft use of the system. The continuity value is normally related only to the risk associated with a missed approach and each aircraft can be considered to be independent. However, in some cases, it may be necessary to increase the continuity values since a system failure has to be correlated between both runways (e.g. the use of a common system for approaches to closely-spaced parallel runways).

3.4.3.3 For GNSS-based APV and Category I approaches, missed approach is considered a normal operation, since it occurs whenever the aircraft descends to the decision altitude for the approach and the pilot is unable to continue with visual reference. The continuity requirement for these operations applies to the average risk (over time) of loss of service, normalized to a 15-second exposure time. Therefore, the specific risk of loss of continuity for a given approach could exceed the average requirement without necessarily affecting the safety of the service provided or the approach. A safety assessment performed for one system led to the conclusion that, in the circumstances specified in the assessment, continuing to provide the service was safer than withholding it.

3.4.3.4 For those areas where the system design does not meet the average continuity risk specified in the SARPs, it is still possible to publish procedures. However, specific operational mitigations should be put in place to cope with the reduced continuity expected. For example, flight planning may not be authorized based on a GNSS navigation means with such a high average continuity risk.

3.5 Availability

3.5.1 The availability of GNSS is characterized by the portion of time the system is to be used for navigation during which reliable navigation information is presented to the crew, autopilot, or other system managing the flight of the aircraft.

3.5.2 When establishing the availability requirements for GNSS, the desired level of service to be supported should be considered. If the satellite navigation service is intended to replace an existing en-route navigation aid infrastructure, the availability of the GNSS should be commensurate with the availability provided by the existing infrastructure. An assessment of the operational impact of a degradation in service should be conducted.

3.5.3 Where GNSS availability is low, it is still possible to use the satellite navigation service by restricting the navigation operating times to those periods when it is predicted to be available. This is possible in the case of GNSS since unavailability due to insufficient satellite geometry is repeatable. Under such restrictions, there remains only a continuity risk associated with the failure of necessary system components between the time the prediction is made and the time the operation is conducted.

3.5.4 *En-route*

3.5.4.1 Specific availability requirements for an area or operation should be based upon:

a) traffic density and complexity;

b) alternate navigation aids;

c) primary/secondary surveillance coverage;

d) air traffic and pilot procedures; and

e) duration of outages.

3.5.4.2 For this reason, the GNSS SARPs specify a range of values for availability requirements. The requirements support GNSS sole-means operations in airspace with various levels of traffic and complexity. The lower end of the range is only sufficient for providing sole means of navigation in a low traffic density and complexity airspace.

3.5.4.3 While augmentations can reduce the dependency of the GNSS on a particular core element, they do not provide usable service without the core elements. The requirement for the availability of a particular augmentation in an area should account for potential degradation in the GNSS core elements (i.e. the minimum constellation of core elements (number and diversity of satellites) that is expected). Operational procedures should be developed in case such a degraded configuration occurs.

3.5.5 *Approach*

3.5.5.1 Specific requirements for an area should be based upon:

a) traffic density and complexity;

b) procedures for filing and conducting an approach to an alternate airport;

c) navigation system to be used for an alternate airport;

d) air traffic and pilot procedures;

e) duration of outages; and

f) geographic extent of outages.

Note.— Allocation of performance requirements between the GBAS subsystems and allocation methodology can be found in RTCA/DO-245, Minimum Aviation System Performance Standards for the Global Positioning System/Local Area Augmentation System (GPS/LAAS). Minimum Operational Performance Standards for GRAS airborne equipment are under development by RTCA.

7.1.2 GBAS ground subsystems provide two services: the approach service and the GBAS positioning service. The approach service provides deviation guidance for FASs in Category I precision approach, APV, and NPA within the operational coverage area. The GBAS positioning service provides horizontal position information to support RNAV operations within the service area. The two services are also distinguished by different performance requirements associated with the particular operations supported (see Table 3.7.2.4-1) including different integrity requirements as discussed in 7.5.1.

7.1.3 A primary distinguishing feature for GBAS ground subsystem configurations is whether additional ephemeris error position bound parameters are broadcast. This feature is required for the positioning service, but is optional for approach services. If the additional ephemeris error position bound parameters are not broadcast, the ground subsystem is responsible for assuring the integrity of ranging source ephemeris data without reliance on the aircraft calculating and applying the ephemeris bound as discussed in 7.5.9.

7.1.4 *GBAS*. There are multiple configurations possible of GBAS ground subsystems conforming to the GNSS Standards, such as:

a) configuration that supports Category I precision approach only;

b) a configuration that supports Category I precision approach and APV, and also broadcasts the additional ephemeris error position bound parameters;

c) a configuration that supports Category I precision approach, APV, and the GBAS positioning service, while also broadcasting the ephemeris error position bound parameters referred to in b); and

d) a configuration that supports APV and the GBAS positioning service, and is used within a GRAS.

7.1.5 *GRAS configurations.* From a user perspective, a GRAS ground subsystem consists of one or more GBAS ground subsystems (as described in 7.1.1 through 7.1.4), each with a unique GBAS identification, providing the positioning service and APV where required. By using multiple GBAS broadcast stations, and by broadcasting the Type 101 message, GRAS is able to support en-route operations via the GBAS positioning service, while also supporting terminal, departure, and APV operations over a larger coverage region than that typically supported by GBAS. In some GRAS applications, the corrections broadcast in the Type 101 message may be computed using data obtained from a network of reference receivers distributed in the coverage region. This permits detection and mitigation of measurement errors and receiver faults.

7.1.6 *VDB transmission path diversity.* All broadcast stations of a GBAS ground subsystem broadcast identical data with the same GBAS identification on a common frequency. The airborne receiver need not and cannot distinguish between messages received from different broadcast stations of the same GBAS ground subsystem. When within coverage of two such broadcast stations, the receiver will receive and process duplicate copies of messages in different time division multiple access (TDMA) time slots.

7.1.7 Interoperability of the GBAS ground and aircraft elements compatible with RTCA/DO-253A is addressed in Appendix B, 3.6.8.1. GBAS receivers compliant with RTCA/DO-253A will not be compatible with GRAS ground subsystems broadcasting Type 101 messages. However, GRAS and GBAS receivers compliant with RTCA GRAS MOPS, will be compatible with GBAS ground subsystems. SARPs-compliant GBAS receivers may not be able to decode the FAS data correctly for APV transmitted from GBAS ground subsystems. These receivers will apply the FASLAL and FASVAL as if conducting a Category I precision approach. Relevant operational restrictions have to apply to ensure the safety of the operation.

7.1.8 The GBAS VDB transmits with either horizontal or elliptical polarization (GBAS/H or GBAS/E). This allows service providers to tailor the broadcast to their operational requirements and user community.

7.1.9 The majority of aircraft will be equipped with a horizontally-polarized VDB receiving antenna, which can be used to receive the VDB from both GBAS/H and GBAS/E equipment. A subset of aircraft will be equipped with a vertically-polarized antenna due to installation limitations or economic considerations. These aircraft are not compatible with GBAS/H equipment and are, therefore, limited to GBAS-based operations supported by GBAS/E.

7.1.10 GBAS service providers must publish the signal polarization (GBAS/H or GBAS/E), for each GBAS facility in the aeronautical information publication (AIP). Aircraft operators that use vertically polarized receiving antenna will have to take this information into account when managing flight operations, including flight planning and contingency procedures.

7.2 RF characteristics

7.2.1 *Frequency coordination*

7.2.1.1 *Performance factors*

7.2.1.1.1 The geographical separation between a candidate GBAS station, a candidate VOR station and existing VOR or GBAS installations must consider the following factors:

a) the coverage volume, minimum field strength and effective radiated power (ERP) of the candidate GBAS including the GBAS positioning service, if provided. The minimum requirements for coverage and field strength are found in Chapter 3, 3.7.3.5.3 and 3.7.3.5.4.4, respectively. The ERP is determined from these requirements;

b) the coverage volume, minimum field strength and ERP of the surrounding VOR and GBAS stations including the GBAS positioning service, if provided. Specifications for coverage and field strength for VOR are found in Chapter 3, 3.3, and respective guidance material is provided in Attachment C;

c) the performance of VDB receivers, including co-channel and adjacent channel rejection, and immunity to desensitization and intermodulation products from FM broadcast signals. These requirements are found in Appendix B, 3.6.8.2.2;

d) the performance of VOR receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing VOR receivers were not specifically designed to reject VDB transmissions, desired-to-undesired (D/U) signal ratios for co-channel and adjacent channel rejection of the VDB were determined empirically. Table D-2 summarizes the assumed signal ratios based upon empirical performance of numerous VOR receivers designed for 50 kHz channel spacing;

e) for areas/regions of frequency congestion, a precise determination of separation may be required using the appropriate criteria;

Table D-2. Assumed $[D/U]_{required}$ signal ratios to protect VOR from GBAS VDB

Frequency offset	$[D/U]_{required}$ ratio to protect VOR receivers (dB)
Co-channel	26
$\| f_{VOR} - f_{VDB} \| = 25$ kHz	0
$\| f_{VOR} - f_{VDB} \| = 50$ kHz	–34
$\| f_{VOR} - f_{VDB} \| = 75$ kHz	–46
$\| f_{VOR} - f_{VDB} \| = 100$ kHz	–65

f) that between GBAS installations RPDS and RSDS numbers are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. The requirement is found in Appendix B, 3.6.4.3.1;

g) that between GBAS installations within radio range of a particular GBAS ground subsystem the reference path identifier is assigned to be unique. The requirement is found in Appendix B, 3.6.4.5.1; and

h) the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Appendix B, 3.6.3.4.1.

7.2.1.1.2 Nominal link budgets for VDB are shown in Table D-3. The first example in Table D-3 assumes a user receiver height of 3 000 m (10 000 ft) MSL and a transmit antenna designed to suppress ground illumination in order to limit the fading losses to a maximum of 10 dB at coverage edge. In the case of GBAS/E equipment, the 10 dB also includes any effects of signal loss due to interference between the horizontal and vertical components. The second example in Table D-3 provides a link budget for longer range positioning service. It is for a user receiver height sufficient to maintain radio line-of-sight with a multi-path limiting transmitting antenna. No margin is given for fading as it is assumed that the receiver is at low elevation angles of radiation and generally free from significant null for the distances shown in the table (greater than 50 NM).

7.2.1.2 *FM immunity*

7.2.1.2.1 Once a candidate frequency is identified for which the GBAS and VOR separation criteria are satisfied, compatibility with FM transmissions must be determined. This is to be accomplished using the methodology applied when determining FM compatibility with VOR. If FM broadcast violates this criterion, an alternative candidate frequency has to be considered.

7.2.1.2.2 The desensitization is not applied for FM carriers above 107.7 MHz and VDB channels at 108.050 MHz because the off-channel component of such high-level emissions from FM stations above 107.7 MHz will interfere with GBAS VDB operations on 108.025 and 108.050 MHz, hence those assignments will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate interference in the VDB receiver.

7.2.1.2.3 The FM intermodulation immunity requirements are not applied to a VDB channel operating below 108.1 MHz, hence assignments below 108.1 MHz will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate intermodulation products in the VDB receiver.

7.2.1.3 *Geographic separation methodologies*

7.2.1.3.1 The methodologies below may be used to determine the required GBAS-to-GBAS and GBAS-to-VOR geographical separation. They rely on preserving the minimum desired-to-undesired signal ratio. $[D/U]_{required}$ is defined as the signal ratio intended to protect the desired signal from co-channel or adjacent channel interference from an undesired transmission. $[D/U]_{required}$ values required for protection of a GBAS receiver from undesired GBAS or VOR signals are defined in Appendix B, 3.6.8.2.2.5 and 3.6.8.2.2.6. $[D/U]_{required}$ values intended for protection of a VOR receiver from GBAS VDB transmissions as shown in Table D-2 are not defined in SARPs and represent the assumed values based on test results.

7.2.1.3.2 Geographic separation is constrained by preserving $[D/U]_{required}$ at the edge of the desired signal coverage where the desired signal power is derived from the minimum field strength requirements in Chapter 3. This desired signal level, converted to dBm, is denoted $P_{D,min}$. The allowed signal power of the undesired signal ($P_{U,allowed}$) is:

$$P_{Uallowed}(dBm) = (P_{D,min}\ (dBm) - [D/U]_{required}\ (dB))$$

The undesired signal power P_U converted to dBm is:

$$P_U(dBm) = (Tx_U\ (dBm) - L\ (dB))$$

where

Tx_U is the effective radiated power of the undesired transmitter; and

L is the transmission loss of the undesired transmitter, including free-space path loss, atmospheric and ground effects. This loss depends upon the distance between the undesired transmitter and the edge of the desired signal coverage.

To ensure $D/U_{required}$ is satisfied, $P_u \leq D_{Uallowed}$. The constraint for assigning a channel is therefore:

$$L(dB) \geq ([D/U]_{required}\ (dB) + Tx_U(dBm) - P_{D,min}\ (dBm))$$

7.2.1.3.3 The transmission loss can be obtained from standard propagation models published in ITU-R Recommendation P.528-2 or from free-space attenuation until the radio horizon and then a constant 0.5 dB/NM attenuation factor. These two methodologies result in slightly different geographical separation for co-channel and first adjacent channels, and identical separation as soon as the second adjacent channel is considered. The free-space propagation approximation is applied in this guidance material.

7.2.1.4 *Example of GBAS/GBAS geographical separation criteria*

7.2.1.4.1 For GBAS VDB co-channel transmissions assigned to the same time slot, the parameters for horizontal polarization are:

D/U = 26 dB (Appendix B, 3.6.8.2.2.5.1);

$P_{D,min}$ = –72 dBm (equivalent to 215 microvolts per metre, Chapter 3, 3.7.3.5.4.4); and

Tx_U = 47 dBm (example link budget, Table D-3);

so

$$L \geq (47 + 26 - (-72)) = 145\ dB.$$

7.2.1.4.2 The geographic separation for co-channel, co-slot GBAS VDB assignments is obtained by determining the distance at which the transmission loss equals 145 dB for receiver altitude of 3 000 m (10 000 ft) above that of the GBAS VDB transmitter antenna. This distance is 318 km (172 NM) using the free-space attenuation approximation and assuming a negligible transmitter antenna height. The minimum required geographical separation can then be determined by adding this distance to the nominal distance between the edge of coverage and the GBAS transmitter 43 km (23 NM). This results in a co-channel, co-slot reuse distance of 361 km (195 NM).

7.2.1.5 *Guidelines on GBAS/GBAS geographical separation criteria*. Using the methodology described above, typical geographic separation criteria can be defined for GBAS to GBAS and GBAS to VOR. The resulting GBAS/GBAS minimum required geographical separation criteria are summarized in Table D-4.

Note.— Geographical separation criteria between the GBAS transmitters providing the GBAS positioning service are under development. A conservative value corresponding to the radiohorizon may be used as an interim value for separation between co-frequency, adjacent time slot transmitters to ensure time slots do not overlap.

7.2.1.6 *Guidelines on GBAS/VOR geographical separation criteria.* The GBAS/VOR minimum geographical separation criteria are summarized in Table D-5 based upon the same methodology and the nominal VOR coverage volumes in Attachment C.

Table D-3. Nominal VDB link budget

VDB link elements					
For approach service		Vertical component at coverage edge		Horizontal component at coverage edge	
Required receiver sensitivity (dBm)		–87		–87	
Maximum aircraft implementation loss (dB)		11		15	
Power level after aircraft antenna (dBm)		–76		–72	
Operating margin (dB)		3		3	
Fade margin (dB)		10		10	
Free space path loss (dB) at 43 km (23 NM)		106		106	
Nominal effective radiated power (ERP) (dBm)		43		47	
For longer range and low radiation angle associated with positioning service		Vertical component		Horizontal component	
Required receiver sensitivity (dBm)		–87		–87	
Maximum aircraft implementation loss (dB)		11		15	
Power level after aircraft antenna (dBm)		–76		–72	
Operating margin (dB)		3		3	
Fade margin (dB)		0		0	
Nominal ERP (dBm)					
Range (km (NM))	Free space loss (dB)	ERP (dBm)	ERP (W)	ERP (dBm)	ERP (W)
93 (50)	113	39.9	10	43.9	25
185 (100)	119	45.9	39	49.9	98
278 (150)	122	49.4	87	53.4	219
390 (200)	125	51.9	155	55.9	389

Notes.—
1. *In this table ERP is referenced to an isotropic antenna model.*
2. *It is possible, with an appropriately sited multipath limiting VDB transmitting antenna with an ERP sufficient to meet the field strength requirements for approach service and considering local topographical limitations, to also satisfy the field strength requirements such that positioning service can be supported at the ranges in this table.*
3. *Actual aircraft implementation loss (including antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the aircraft implementation loss for the horizontal component is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve -91 dBm to satisfy the nominal link budget.*

Note 1.— When determining the geographical separation between VOR and GBAS, VOR as the desired signal is generally the constraining case due to the greater protected altitude of the VOR coverage region.

Note 2.— Reduced geographical separation requirements can be Pobtained using standard propagation models defined in ITU-R Recommendation P.528-2.

7.2.2 The geographical separation criteria for GBAS/ILS and GBAS/VHF communications are under development.

7.2.3 *Compatibility with ILS*. Until compatibility criteria are developed for GBAS VDB and ILS, VDB cannot be assigned to channels below 112.025 MHz. If there is an ILS with a high assigned frequency at the same airport as a VDB with a frequency near 112 MHz, it is necessary to consider ILS and VDB compatibility. Considerations for assignment of VDB channels include the frequency separation between the ILS and the VDB, the distance separation between the ILS coverage area and the VDB, the VDB and ILS field strengths, and the VDB and ILS sensitivity. For GBAS equipment with transmitter power of up to 150 W (GBAS/E, 100 W for horizontal component and 50 W for vertical component) or 100 W (GBAS/H), the 16th channel (and beyond) will be below –106 dBm at a distance of 200 m from the VDB transmitter, including allowing for a +5 dB positive reflection. This –106 dBm figure assumes a –86 dBm localizer signal at the ILS receiver input and a minimum 20 dB signal-to-noise ratio.

7.2.4 *Compatibility with VHF communications*. For GBAS VDB assignments above 116.400 MHz, it is necessary to consider VHF communications and GBAS VDB compatibility. Considerations for assignment of these VDB channels include the frequency separation between the VHF communication and the VDB, the distance separation between the transmitters and coverage areas, the field strengths, the polarization of the VDB signal, and the VDB and VHF sensitivity. Both aircraft and ground VHF communication equipment are to be considered. For GBAS/E equipment with a transmitter maximum power of up to 150 W (100 W for horizontal component and 50 W for vertical component), the 64th channel (and beyond) will be below –120 dBm at a distance of 200 m from the VDB transmitter including allowing for a +5 dB positive reflection. For GBAS/H equipment with a transmitter maximum power of 100 W, the 32nd channel (and beyond) will be below –120 dBm at a distance of 200 m from the VDB transmitter including allowing for a +5 dB positive reflection, and a 10 dB polarization isolation. It must be noted that due to differences in the VDB and VDL transmitter masks, separate analysis must be performed to ensure VDL does not interfere with the VDB.

Table D-4. Typical GBAS/GBAS frequency assignment criteria

Channel of undesired VDB in the same time slots	Path loss (dB)	Minimum required geographical separation for Tx_U = 47 dBm and $P_{D,min}$ = –72 dBm in km (NM)
Cochannel	145	361 (195)
1st adjacent channel (±25 kHz)	101	67 (36)
2nd adjacent channel (±50 kHz)	76	44 (24)
3rd adjacent channel (±75 kHz)	73	No restriction
4th adjacent channel (±100 kHz)	73	No restriction

Note.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB transmitting antenna is located at least 200 m from areas where the desired signal is at minimum field strength.

Table D-5. Minimum required geographical separation for a VOR coverage (12 000 m (40 000 ft) level)

Channel of undesired GBAS VDB	Path loss (dB)	VOR coverage radius		
		342 km (185 NM)	300 km (162 NM)	167 km (90 NM)
Co-channel	152	892 km (481 NM)	850 km (458 NM)	717 km (386 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 25 kHz	126	774 km (418 NM)	732 km (395 NM)	599 km (323 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 50 kHz	92	351 km (189 NM)	309 km (166 NM)	176 km (94 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 75 kHz	80	344 km (186 NM)	302 km (163 NM)	169 km (91 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 100 kHz	61	No restriction	No restriction	No restriction

Note.— Calculations are based on reference frequency of 112 MHz and assume GBAS Tx_U = 47 dBm and VOR $P_{D,min}$ = –79 dBm.

7.2.5 For a GBAS ground subsystem that only transmits a horizontally-polarized signal, the requirement to achieve the power associated with the minimum sensitivity is directly satisfied through the field strength requirement. For a GBAS ground subsystem that transmits an elliptically-polarized component, the ideal phase offset between HPOL and VPOL components is 90 degrees. In order to ensure that an appropriate received power is maintained throughout the GBAS coverage volume during normal aircraft manoeuvres, transmitting equipment should be designed to radiate HPOL and VPOL signal components with an RF phase offset of 90 degrees. This phase offset should be consistent over time and environmental conditions. Deviations from the nominal 90 degrees must be accounted for in the system design and link budget, so that any fading due to polarization loss does not jeopardize the minimum receiver sensitivity. System qualification and flight inspection procedures will take into account an allowable variation in phase offset consistent with maintaining the appropriate signal level throughout the GBAS coverage volume. One method of ensuring both horizontal and vertical field strength is to use a single VDB antenna that transmits an elliptically-polarized signal, and flight inspect the effective field strength of the vertical and horizontal signals in the coverage volume.

7.3 Coverage

7.3.1 The GBAS coverage to support approach services is depicted in Figure D-4. When the additional ephemeris error position bound parameters are broadcast, differential corrections may only be used within the Maximum Use Distance (D_{max}) defined in the Type 2 message. Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach.

7.3.2 The coverage required to support the GBAS positioning service is dependent upon the specific operations intended. The optimal coverage for this service is intended to be omnidirectional in order to support operations using the GBAS positioning service that are performed outside of the precision approach coverage volume. Each State is responsible for defining a service area for the GBAS positioning service and ensuring that the requirements of Chapter 3, 3.7.2.4 are satisfied. When making this determination, the characteristics of the fault-free GNSS receiver should be considered, including the reversion to ABAS-based integrity in the event of loss of GBAS positioning service.

7.3.3 The limit on the use of the GBAS positioning service information is given by the Maximum Use Distance (D_{max}), which defines the range within which the required integrity is assured and differential corrections can be used for either the positioning service or precision approach. D_{max} however does not delineate the coverage area where field strength requirements specified in Chapter 3, 3.7.3.5.4.4 are met nor matches this area. Accordingly, operations based on the GBAS positioning service can be predicated only in the coverage area(s) (where the field strength requirements are satisfied) within the D_{max} range.

7.3.4 As the desired coverage area of a GBAS positioning service may be greater than that which can be provided by a single GBAS broadcast station, a network of GBAS broadcast stations can be used to provide the coverage. These stations can broadcast on a single frequency and use different time slots (8 available) in neighbouring stations to avoid interference or they can broadcast on different frequencies. Figure D-4A details how the use of different time slots will allow a single frequency to be used without interference subject to guard time considerations noted under Table B-59. For a network based on different VHF frequencies, guidance material in 7.17 should be considered.

7.4 Data structure

A bit scrambler/descrambler is shown in Figure D-5.

Note.— Additional information on the data structure of the VHF data broadcast is given in RTCA/DO-246B, GNSS Based Precision Approach Local Area Augmentation System (LAAS)—Signal-in-Space Interface Control Document (ICD).

7.5 Integrity

7.5.1 Different levels of integrity are specified for precision approach operations and operations based on the GBAS positioning service. The signal-in-space integrity risk for Category I is 2×10^{-7} per approach. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service have to also meet the signal-in-space integrity risk requirement specified for terminal area operations, which is 1×10^{-7}/hour (Chapter 3, Table 3.7.2.4-1). Therefore additional measures are necessary to support these more stringent requirements for positioning service. The signal-in-space integrity risk is allocated between the ground subsystem integrity risk and the protection level integrity risk. The ground subsystem integrity risk allocation covers failures in the ground subsystem as well as core constellation and SBAS failures such as signal quality failures and ephemeris failures. The protection level integrity risk allocation covers rare fault-free performance risks and the case of failures in one of the reference receiver measurements. In both cases the protection level equations ensure that the effects of the satellite geometry used by the aircraft receiver are taken into account. This is described in more detail in the following paragraphs.

7.5.2 The GBAS ground subsystem defines a corrected pseudo-range error uncertainty for the error relative to the GBAS reference point (σ_{pr_gnd}) and the errors resulting from vertical (σ_{tropo}) and horizontal (σ_{iono}) spatial decorrelation. These uncertainties are modelled by the variances of zero-mean, normal distributions which describe these errors for each ranging source.

7.5.3 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. General methods for determining that the model variance is adequate to guarantee the protection level integrity risk are described in Section 14. The lateral protection level (LPL) provides a bound on the lateral position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. For Category I precision approach and APV, if the computed LPL exceeds the lateral alert limit (LAL) or the VPL exceeds the vertical alert limit (VAL), integrity is not adequate to support the operation. For the positioning service the alert limits are not defined in the standards, with only the horizontal protection level and ephemeris error position bounds required to be computed and applied. The alert limits will be determined based on the operation being conducted. The aircraft will apply the computed protection level and ephemeris bounds by verifying they are smaller than the alert limits. Two protection levels are defined, one to address the condition when all reference receivers are fault-free (H_0 – Normal Measurement Conditions), and one to address the condition when one of the reference receivers contains failed measurements (H_1 – Faulted Measurement Conditions). Additionally an ephemeris error position bound provides a bound on the position error due to failures in ranging source ephemeris. For Category I precision approach and APV, a lateral error bound (LEB) and a vertical error bound (VEB) are defined. For the positioning service a horizontal ephemeris error bound (HEB) is defined.

7.5.4 *Ground system contribution to corrected pseudo-range error (σ_{pr_gnd})*. Error sources that contribute to this error include receiver noise, multipath, and errors in the calibration of the antenna phase centre. Receiver noise has a zero-mean, normally distributed error, while the multipath and antenna phase centre calibration can result in a small mean error.

7.5.5 *Residual tropospheric errors*. Tropospheric parameters are broadcast in Type 2 messages to model the effects of the troposphere, when the aircraft is at a different height than the GBAS reference point. This error can be well-characterized by a zero-mean, normal distribution.

7.5.6 *Residual ionospheric errors*. An ionospheric parameter is broadcast in Type 2 messages to model the effects of the ionosphere between the GBAS reference point and the aircraft. This error can be well-characterized by a zero-mean, normal distribution.

7.5.7 *Aircraft receiver contribution to corrected pseudo-range error*. The receiver contribution is bounded as described in Section 14. The maximum contribution, used for analysis by the GBAS provider, can be taken from the accuracy requirement, where it is assumed that $\sigma_{receiver}$ equals RMS_{pr_air} for GBAS Airborne Accuracy Designator A equipment.

7.5.8 *Airframe multipath error*. The error contribution from airframe multipath is defined in Appendix B, 3.6.5.5.1. Multipath errors resulting from reflections from other objects are not included. If experience indicates that these errors are not negligible, they must be accounted for operationally or through inflation of the parameters broadcast by the ground (e.g. σ_{pr_gnd}).

7.5.9 *Ephemeris error uncertainty*. Pseudo-range errors resulting from ephemeris errors (defined as a discrepancy between the true satellite position and the satellite position determined from the broadcast data) are spatially decorrelated and will therefore be different for receivers in different locations. When users are relatively close to the GBAS reference point, the residual differential error due to ephemeris errors will be small and both the corrections and uncertainty parameters σ_{pr_gnd} sent by the ground subsystem will be valid to correct the raw measurements and compute the protection levels. For users further away from the GBAS reference point, protection against ephemeris failures can be ensured in two different ways:

a) the ground subsystem does not transmit the additional ephemeris error position bound parameters. In this case, the ground subsystem is responsible for assuring integrity in case of satellite ephemeris failures without reliance on the aircraft calculating and applying the ephemeris bound. This may impose a restriction on the distance between the GBAS reference point and the decision altitude/height depending upon the ground subsystem means of detecting ranging source ephemeris failures. One means of detection is to use satellite integrity information broadcast by SBAS; and

b) the ground subsystem transmits the additional ephemeris error position bound parameters which enable the airborne receiver to compute an ephemeris error bound. These parameters are: coefficients used in the ephemeris error position bound equations ($K_{md\_e\_()}$, where the subscript () means either “GPS”, “GLONASS”, “POS, GPS” or “POS, GLONASS”), the maximum use distance for the differential corrections (D_{max}), and the ephemeris decorrelation parameters (P). The ephemeris decorrelation parameter (P) in the Type 1 or Type 101 message characterizes the residual error as a function of distance between the GBAS reference point and the aircraft. The value of P is expressed in m/m. The values of P are determined by the ground subsystem for each satellite. One of the main factors influencing the values of P is the ground subsystem monitor design. The quality of the ground monitor will be characterized by the smallest ephemeris error (or minimum detectable error (MDE)) that it can detect. The relationship between the P parameter and the MDE for a particular satellite can be approximated by $P_i = MDE_i/R_i$ where R_i is the smallest of the predicted ranges from the ground subsystem reference receiver antenna(s) for the period of validity of P_i. Being dependent on satellite geometry, the P parameters values are slowly varying. However, it is not a requirement for the ground subsystem to dynamically vary P. Static P parameters could be sent if they properly ensure integrity. In this latter case, the availability would be slightly degraded. Generally, as MDE becomes smaller, overall GBAS availability improves.

7.5.10 *Ephemeris error/failure monitoring*. There are several types of monitoring approaches for detecting ephemeris errors/failures. They include:

a) *Long baseline*. This requires the ground subsystem to use receivers separated by large distances to detect ephemeris errors that are not observable by a single receiver. Longer baselines translate to better performance in MDE;

b) *SBAS*. Since SBAS augmentation provides monitoring of satellite performance, including ephemeris data, integrity information broadcast by SBAS can be used as an indication of ephemeris validity. SBAS uses ground subsystem receivers installed over very long baselines, therefore this provides optimum performance for ephemeris monitoring and thus achieves small MDEs; and

c) *Ephemeris data monitoring*. This approach involves comparing the broadcast ephemeris over consecutive satellite orbits. There is an assumption that the only threat of failure is due to a failure in ephemeris upload from the constellation ground control network. Failures due to uncommanded satellite manoeuvres must be sufficiently improbable to ensure that this approach provides the required integrity.

7.5.10.1 The monitor design (for example, its achieved MDE) is to be based upon the integrity risk requirements and the failure model the monitor is intended to protect against. A bound on the GPS ephemeris failure rate can be determined from the reliability requirements defined in Chapter 3, 3.7.3.1.3, since such an ephemeris error would constitute a major service failure.

7.5.10.2 The GLONASS control segment monitors the ephemeris and time parameters, and in case of any abnormal situation it starts to input the new and correct navigation message. The ephemeris and time parameter failures do not exceed 70 m of range errors. The failure rate of GLONASS satellite including the ephemeris and time parameter failures does not exceed 4×10^{-5} per satellite per hour.

7.5.11 A typical GBAS ground subsystem processes measurements from 2 to 4 reference receivers installed in the immediate vicinity of the reference point. The aircraft receiver is protected against a large error or fault condition in a single reference receiver by computing and applying the B parameters from the Type 1 or Type 101 message to compare data from the various reference receivers. Alternative system architectures with sufficiently high redundancy in reference receiver measurements may employ processing algorithms capable of identifying a large error or fault in one of the receivers. This may apply for a GRAS network with receivers distributed over a wide area and with sufficient density of ionospheric pierce points to separate receiver errors from ionospheric effects. The integrity can then be achieved using only the protection levels for normal measurement conditions (VPL_{H0} and LPL_{H0}), with appropriate values for K_{ffmd} and σ_{pr_gnd}. This can be achieved using the Type 101 message with the B parameters excluded.

7.6 Continuity of service

7.6.1 *Ground continuity and integrity designator*. The ground continuity and integrity designator (GCID) provides a classification of GBAS ground subsystems. The ground subsystem meets the requirements of Category I precision approach or APV when GCID is set to 1. GCID 2, 3 and 4 are intended to support future operations with requirements that are more stringent than Category I operations. The GCID is intended to be an indication of ground subsystem status to be used when an aircraft selects an approach. It is not intended to replace or supplement an instantaneous integrity indication communicated in a Type 1 or Type 101 message. GCID does not provide any indication of the ground subsystem capability to support the GBAS positioning service.

7.6.2 *Ground subsystem continuity of service*. GBAS ground subsystems are required to meet the continuity specified in Appendix B to Chapter 3, 3.6.7.1.3 in order to support Category I precision approach and APV. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service should support the minimum continuity required for terminal area operations, which is $1–10^{-4}$/hour (Chapter 3, Table 3.7.2.4-1). When the Category I precision approach or APV required continuity ($1–8 \times 10^{-6}$/15 seconds) is converted to a per hour value it does not meet the $1–10^{-4}$/hour minimum continuity requirement. Therefore, additional measures are necessary to meet the continuity required for other operations. One method of showing compliance with this requirement is to assume that airborne implementation uses both GBAS and ABAS to provide redundancy and that ABAS provides sufficient accuracy for the intended operation.

7.7 GBAS channel selection

7.7.1 Channel numbers are used in GBAS to facilitate an interface between aircraft equipment and the signal-in-space that is consistent with interfaces for ILS and MLS. The cockpit integration and crew interface for GBAS may be based on entry of the 5-digit channel number. An interface based on approach selection through a flight management function similar to current practice with ILS is also possible. The GBAS channel number may be stored in an on-board navigation database as part of a named approach. The approach may be selected by name and the channel number can automatically be provided to the equipment that must select the appropriate GBAS approach data from the broadcast data. Similarly, the use of the GBAS positioning service may be based on the selection of a 5-digit channel number. This facilitates conducting operations other than the approaches defined by the FAS data. To facilitate frequency tuning, the GBAS channel numbers for neighbouring GBAS ground subsystems supporting positioning service may be provided in the Type 2 message additional data block 2.

7.7.2 A channel number in the range from 20 001 to 39 999 is assigned when the FAS data are broadcast in the Type 4 message. A channel number in the range from 40 000 to 99 999 is assigned when the FAS data associated with an APV are obtained from the on-board database.

7.8 Reference path data selector and reference station data selector

A mapping scheme provides a unique assignment of a channel number to each GBAS approach. The channel number consists of five numeric characters in the range 20 001 to 39 999. The channel number enables the GBAS airborne subsystem to tune to the correct frequency and select the final approach segment (FAS) data block that defines the desired approach. The correct FAS data block is selected by the reference path data selector (RPDS), which is included as part of the FAS definition data in a Type 4 message. Table D-6 shows examples of the relationship between the channel number, frequency and RPDS. The same mapping scheme applies to selection of the positioning service through the reference station data selector (RSDS). The RSDS is broadcast in the Type 2 message and allows the selection of a unique GBAS ground subsystem that provides the positioning service. For GBAS ground subsystems that do not provide the positioning service and broadcast the additional ephemeris data, the RSDS is coded with a value of 255. All RPDS and RSDS broadcast by a ground subsystem must be unique on the broadcast frequency within radio range of the signal. The RSDS value must not be the same as any of the broadcast RPDS values.

7.9 Assignment of RPDS and RSDS by service provider

RPDS and RSDS assignments are to be controlled to avoid duplicate use of channel numbers within the protection region for the data broadcast frequency. Therefore, the GBAS service provider has to ensure that an RPDS and RSDS are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. Assignments of RPDS and RSDS are to be managed along with assignments of frequency and time slots for the VHF data broadcast.

Table D-6. Channel assignment examples

Channel number (N)	Frequency in MHz (F)	Reference path data selector (RPDS) or Reference station data selector (RSDS)
20 001	108.025	0
20 002	108.05	0
20 003	108.075	0
….	….	….
20 397	117.925	0
20 398	117.95	0
20 412 (Note)	108.025	1
20 413	108.05	1
….	….	….

Note.— Channels between 20 398 and 20 412 are not assignable because the channel algorithm maps them to frequencies outside the range of 108.025 MHz and 117.950 MHz. A similar "gap" in the channel assignments occurs at each RPDS transition.

7.10 GBAS identification

The GBAS identification (ID) is used to uniquely identify a GBAS ground subsystem broadcasting on a given frequency within the coverage region of the GBAS. The aircraft will navigate using data broadcast from one or more GBAS broadcast stations of a single GBAS ground subsystem (as identified by a common GBAS identification).

7.11 Final approach segment (FAS) path

7.11.1 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 glide path angle (GPA). These parameters are determined from data provided in a FAS data block within a Type 4 message or in the on-board database. The relationship between these parameters and the FAS path is illustrated in Figure D-6.

7.11.1.1 FAS data blocks for SBAS and some GBAS approaches are held within a common onboard database supporting both SBAS and GBAS. States are responsible for providing the FAS data to support APV procedures when the Type 4 message is not broadcast. These data comprise the parameters contained within the FAS block, the RSDS, and associated broadcast frequency. The FAS block for a particular approach procedure is described in Appendix B, 3.6.4.5.1 and Table B-66.

7.11.2 *FAS path definition*

7.11.2.1 *Lateral orientation*. The LTP/FTP is typically at or near the runway threshold. However, to satisfy operational needs or physical constraints, the LTP/FTP may not be at the threshold. The FPAP is used in conjunction with the LTP/FTP to define the lateral reference plane for the approach. For a straight-in approach aligned with the runway, the FPAP will be at or beyond the stop end of the runway. The FPAP is not placed before the stop end of the runway.

7.11.2.2 *ΔLength offset*. The Δlength offset defines the distance from the end of the runway to the FPAP. This parameter is provided to enable the aircraft equipment to compute the distance to the end of the runway. If the Δlength offset is not set to appropriately indicate the end of the runway relative to the FPAP, the service provider should ensure the parameter is coded as "not provided".

7.11.2.3 *Vertical orientation*. Local vertical for the approach is defined as normal to the WGS-84 ellipsoid at the LTP/FTP and may differ significantly from the local gravity vector. The local level plane for the approach is defined as a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). The datum crossing point (DCP) is a point at a height defined by TCH above the LTP/FTP. The FAS path is defined as a line with an angle (defined by the GPA) relative to the local level plane passing through the DCP. The GPIP is the point where the final approach path intercepts the local level plane. The GPIP may actually be above or below the runway surface depending on the curvature of the runway.

7.11.3 *"ILS look-alike" deviation computations*. For compatibility with existing aircraft designs, it is desirable for aircraft equipment to output guidance information in the form of deviations relative to a desired flight path defined by the FAS path. The Type 4 message includes parameters that support the computation of deviations that are consistent with typical ILS installations.

7.11.3.1 *Lateral deviation definition*. Figure D-6 illustrates the relationship between the FPAP and the origin of the lateral angular deviations. The course width parameter and FPAP are used to define the origin and sensitivity of the lateral deviations. By adjusting the location of the FPAP and the value of the course width, the course width and sensitivity of a GBAS can be set to the desired values. They may be set to match the course width and sensitivity of an existing ILS or MLS. This may be necessary, for example, for compatibility with existing visual landing aids.

7.11.3.1.1 *Lateral deviation reference*. The lateral deviation reference plane is the plane that includes the LTP/FTP, FPAP and a vector normal to the WGS-84 ellipsoid at the LTP/FTP. The rectilinear lateral deviation is the distance of the computed aircraft position from the lateral deviation reference plane. The angular lateral deviation is a corresponding angular displacement referenced to the GBAS azimuth reference point (GARP). The GARP is defined to be beyond the FPAP along the procedure centre line by a fixed offset value of 305 m (1 000 ft).

7.11.3.1.2 *Lateral displacement sensitivity*. The lateral displacement sensitivity is determined by the aircraft equipment from the course width provided in the FAS data block. The service provider is responsible for setting the course width parameter to a value that results in the appropriate angle for full scale deflection (i.e. 0.155 DDM or 150 µA) taking into account any operational constraints.

7.11.3.2 *Vertical deviations*. Vertical deviations are computed by the aircraft equipment with respect to a GBAS elevation reference point (GERP). The GERP may be at the GPIP or laterally offset from the GPIP by a fixed GERP offset value of 150 m. Use of the offset GERP allows the glide path deviations to produce the same hyperbolic effects that are normal characteristics of ILS and MLS (below 200 ft). The decision to offset the GERP or not is made by the aircraft equipment in accordance with requirements driven by compatibility with existing aircraft systems. Service providers should be aware that users may compute vertical deviations using a GERP which is placed at either location. Sensitivity of vertical deviations is set automatically in the aircraft equipment as a function of the GPA. The specified relationship between GPA and the full scale deflection (FSD) of the vertical deviation sensitivity is: FSD = 0.25*GPA. The value 0.25 is the same as for MLS (Attachment G, 7.4.1.2) and differs slightly from the nominal value of 0.24 recommended for ILS (Chapter 3, section 3.1.5.6.2). However, the value specified is well within the tolerances recommended for ILS (0.2 to 0.28). Therefore the resulting sensitivity is equivalent to the glide path displacement sensitivity provided by a typical ILS.

7.11.4 *Approaches not aligned with the runway*. Some operations may require the definition of a FAS path that is not aligned with the runway centre line as illustrated in Figure D-7. For approaches not aligned with the runway, the LTP/FTP may or may not lie on the extended runway centre line. For this type of approach Δlength offset is not meaningful and should be set to “not provided”.

7.11.5 *SBAS service provider.* A common format is used for FAS data blocks to be used by both GBAS and SBAS. The SBAS service provider ID field identifies which SBAS system(s) may be used by an aircraft that is using the FAS data during an approach. The GBAS service provider may inhibit use of the FAS data in conjunction with any SBAS service. For precision approaches based on GBAS this field is not used, and it can be ignored by aircraft GBAS equipment.

7.11.6 *Approach identifier*. The service provider is responsible for assigning the approach identifier for each approach. The approach identification should be unique within a large geographical area. Approach identifications for multiple runways at a given aerodrome should be chosen to reduce the potential for confusion and misidentification. The approach identification should appear on the published charts that describe the approach. The first letter of the approach identifier is used in the authentication protocols for GBAS. Ground stations that support the authentication protocols must encode the first character of the identifier for all approaches supported from the set of letters {A X Z J C V P T} as described in Appendix B, section 3.6.7.4.1.4. This enables airborne equipment (that supports the authentication protocols) to determine which slots are assigned to the ground station and therefore to subsequently ignore reception of data broadcast in slots not assigned to the selected ground station. For ground stations that do not support the authentication protocols, the first character of the approach identifier may be assigned any character except those in the set {A X Z J C V P T}.

7.12 Airport siting considerations

7.12.1 The installation of a GBAS ground subsystem involves special considerations in choosing prospective sites for the reference receiver antennas and the VDB antenna(s). In planning antenna siting, Annex 14 obstacle limitation requirements must be met.

7.12.2 *Locating reference receiver antennas*. The site should be selected in an area free of obstructions, so as to permit the reception of satellite signals at elevation angles as low as possible. In general, anything masking GNSS satellites at elevation angles higher than 5 degrees will degrade system availability.

7.12.2.1 The antennas for the reference receivers should be designed and sited to limit multipath signals that interfere with the desired signal. Mounting antennas close to a ground plane reduces long-delay multipath resulting from reflections below the antenna. Mounting height should be sufficient to prevent the antenna being covered by snow, or being interfered with by maintenance personnel or ground traffic. The antenna should be sited so that any metal structures, such as air vents, pipes and other antennas are outside the near-field effects of the antenna.

7.12.2.2 Besides the magnitude of the multipath error at each reference receiver antenna location, the degree of correlation must also be considered. Reference receiver antennas should be located in places that provide independent multipath environments.

7.12.2.3 The installation of each antenna should include a mounting that will not flex in winds or under ice loads. Reference receiver antennas should be located in an area where access is controlled. Traffic may contribute to error due to multipath or obstruct view of satellites from the antennas.

7.12.3 *Locating the VDB antenna*. The VDB antenna should be located so that an unobstructed line-of-sight exists from the antenna to any point within the coverage volume for each supported FAS. Consideration should also be given to ensuring the minimum transmitter-to-receiver separation so that the maximum field strength is not exceeded. In order to provide the required coverage for multiple FASs at a given airport, and in order to allow flexibility in VBD antenna siting, the actual coverage volume around the transmitter antenna may need to be considerably larger than that required for a single FAS. The ability to provide this coverage is dependent on the VDB antenna location with respect to the runway and the height of the VDB antenna. Generally speaking, increased antenna height may be needed to provide adequate signal strength to users at low altitudes, but may also result in unacceptable multipath nulls within the desired coverage volume. A suitable antenna height trade-off must be made based on analysis, to ensure the signal strength requirements are met within the entire volume. Consideration should also be given to the effect of terrain features and buildings on the multipath environment.

7.12.4 *Use of multiple transmit antennas to improve VDB coverage.* For some GBAS installations, constraints on antenna location, local terrain or obstacles may result in ground multipath and/or signal blockage that make it difficult to provide the specified field strength at all points within the coverage area. Some GBAS ground facilities may make use of one or more additional antenna systems, sited to provide signal path diversity such that collectively they meet the coverage requirements.

7.12.4.1 Whenever multiple antenna systems are used, the antenna sequence and message scheduling must be arranged to provide broadcasts at all points within the coverage area that adhere to the specified minimum and maximum data broadcast rates and field strengths, without exceeding the receiver's ability to adapt to transmission-to-transmission variations in signal strength in a given slot. To avoid receiver processing issues concerning lost or duplicated messages, all transmissions of the Type 1 or Type 101 message, or linked pair of Type 1 or Type 101 messages for a given measurement type within a single frame need to provide identical data content.

7.12.4.2 One example of the use of multiple antennas is a facility with two antennas installed at the same location but at different heights above the ground plane. The heights of the antennas are chosen so that the pattern from one antenna fills the nulls in the pattern of the other antenna that result from reflections from the ground plane. The GBAS ground subsystem alternates broadcasts between the two antennas, using one or two assigned slots of each frame for each antenna. Type 1 or Type 101 messages are broadcast once per frame, per antenna. This allows for reception of one or two Type 1 or Type 101 messages per frame, depending on whether the user is located within the null of one of the antenna patterns. Type 2 and 4 messages are broadcast from the first antenna in one frame, then from the second antenna in the next frame. This allows for reception of one each of the Type 2 and 4 messages per one or two frames, depending on the user location.

7.13 Definition of lateral and vertical alert limits

7.13.1 The lateral and vertical alert limits for Category I precision approach are computed as defined in Appendix B, Tables B-68 and B-69. In these computations the parameters D and H have the meaning shown in Figure D-8.

7.13.2 The vertical alert limit for Category I precision approach is scaled from a height of 60 m (200 ft) above the LTP/FTP. For a procedure designed with a decision height of more than 60 m (200 ft), the VAL at that decision height will be larger than the broadcast FASVAL.

7.13.3 The lateral and vertical alert limits for APV procedures associated with channel numbers 40 001 to 99 999 are computed in the same manner as for APV procedures using SBAS as given in Attachment D, 3.2.8.

7.14 Monitoring and maintenance actions

7.14.1 Specific monitoring requirements or built-in tests may be necessary and should be determined by individual States. Since the VDB signal is critical to the operation of the GBAS broadcast station, any failure of the VDB to successfully transmit a usable signal within the assigned slots and over the entire coverage area is to be corrected as soon as possible. Therefore, it is recommended that the following conditions be used as a guide for implementing a VDB monitor:

a) *Power.* A significant drop in power is to be detected within 3 seconds.

b) *Loss of message type.* The failure to transmit any scheduled message type(s). This could be based on the failure to transmit a unique message type in succession, or a combination of different message types.

c) *Loss of all message types.* The failure to transmit any message type for a period equal to or greater than 3 seconds will be detected.

7.14.2 Upon detection of a failure, and in the absence of a backup transmitter, termination of the VDB service should be considered if the signal cannot be used reliably within the coverage area to the extent that aircraft operations could be significantly impacted. Appropriate actions in operational procedures are to be considered to mitigate the event of the signal being removed from service. These would include dispatching maintenance specialists to service the GBAS VDB or special ATC procedures. Additionally, maintenance actions should be taken when possible for all built-in test failures to prevent loss of GBAS service.

7.15 Examples of VDB messages

7.15.1 Examples of the coding of VDB messages are provided in Tables D-7 through D-10. The examples illustrate the coding of the various application parameters, including the cyclic redundancy check (CRC) and forward error correction (FEC) parameters, and the results of bit scrambling and D8PSK symbol coding. The engineering values for the message parameters in these tables illustrate the message coding process, but are not necessarily representative of realistic values.

7.15.2 Table D-7 provides an example of a Type 1 VDB message. 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. This is done for illustration purposes; a second Type 1 message is not typically required, except to allow broadcast of more ranging source corrections than can be accommodated in a single message.

7.15.3 Table D-7A provides an example of a Type 101 VDB message. The additional message flag field is coded to indicate that this is the first of two Type 101 messages to be broadcast within the same frame. This is done for illustration purposes; a second Type 101 message is not typically required, except to allow broadcast of more ranging source corrections than can be accommodated in a single message.

7.15.4 Table D-8 provides examples of a Type 1 VDB message and a Type 2 VDB 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. Table D-8A provides an example of Type 1 and Type 2 messages with additional data blocks 1 and 2.

7.15.4.1 Table D-8B provides an example of Type 2 messages with additional data blocks 1 and 4 coded within a single burst with a Type 3 message that is used to fill the rest of the time slot.

7.15.5 Table D-9 provides an example of a Type 4 message containing two FAS data blocks.

7.15.6 Table D-10 provides an example of a Type 5 message. In this example, source availability durations common to all approaches are provided for two ranging sources. Additionally, source availability durations for two individual approaches are provided: the first approach has two impacted ranging sources and the second approach has one impacted ranging source. The Type 2 message includes additional data block 1.

7.16 GBAS survey accuracy

The standards for the survey accuracy for NAVAIDs are contained in Annex 14 — *Aerodromes*. In addition, the *Manual of the World Geodetic System 1984 (WGS-84)* (Doc 9674) provides guidance on the establishment of a network of survey control stations at each aerodrome and how to use the network to establish WGS-84 coordinates. Until specific requirements are developed for GBAS, the Annex 14 survey accuracy requirements for NAVAIDs located at the aerodrome apply to GBAS. The recommendation contained in Appendix B to Chapter 3, 3.6.7.2.3.4, for the survey accuracy of the GBAS reference point is intended to further reduce the error in the WGS-84 position calculated by an airborne user of the GBAS positioning service to a value smaller than that established by the requirements of Appendix B to Chapter 3, 3.6.7.2.4.1 and 3.6.7.2.4.2, in the GBAS standards and to enhance survey accuracy compared to that specified in Annex 14. The integrity of all aeronautical data used for GBAS is to be consistent with the integrity requirements in Chapter 3, Table 3.7.2.4-1.

7.17 Type 2 message additional data blocks

7.17.1 The Type 2 message contains data related to the GBAS facility such as the GBAS reference point location, the GBAS continuity and integrity designator (GCID) and other pertinent configuration information. A method for adding new data to the Type 2 message has been devised to allow GBAS to evolve to support additional service types. The method is through the definition of new additional data blocks that are appended to the Type 2 message. In the future, more additional data blocks may be defined. Data blocks 2 through 255 have variable length and may be appended to the message after additional data block 1 in any order.

7.17.2 Type 2 message additional data block 1 contains information related to spatial decorrelation of errors and information needed to support selection of the GBAS positioning service (when provided by a given ground station).

7.17.3 Type 2 message additional data block 2 data may be used in GRAS to enable the GRAS airborne subsystem to switch between GBAS broadcast stations, particularly if the GBAS broadcast stations utilize different frequencies. Additional data block 2 identifies the channel numbers and locations of the GBAS broadcast station currently being received and other adjacent or nearby GBAS broadcast stations.

7.17.4 Type 2 message additional data block 3 is reserved for future use.

7.17.5 Type 2 message additional data block 4 contains information necessary for a ground station that supports the authentication protocols. It includes a single parameter which indicates which slots are assigned to the ground station for VDB transmissions. Airborne equipment that supports the authentication protocols will not use data unless it is transmitted in the slots indicated by the slot group definition field in the MT 2 ADB 4.

Table D-7. Example of a Type 1 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	100
Transmission length (bits)	17	0 to 1 824 bits	1 bit	536	000 0000 1000 0110 00
Training sequence FEC	5	—	—	—	0000 1
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 1 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	61	0011 1101
Message (Type 1 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	1st of pair	01
Number of measurements	5	0 to 18	1	4	0 0100
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 $\times 10^{-3}$m/m	5×10^{-6}m/m	1×10^{-4}	0001 0100
Ephemeris CRC	16	—	—	—	0000 0000 0000 0000
Source availability duration	8	0 to 2 540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	2	0000 0010
Issue of data (IOD)	8	0 to 255	1	255	1111 1111
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 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 to 255	1	4	0000 0100
Issue of data (IOD)	8	0 to 255	1	126	0111 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	–1.0 m	1111 1111 1001 1100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	+0.2 m/s	0000 0000 1100 1000
σ_{pr_gnd}	8	0 to 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
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

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Measurement Block 3					
Ranging source ID	8	1 to 255	1	12	0000 1100
Issue of data (IOD)	8	0 to 255	1	222	1101 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.11 m	0000 0000 0110 1111
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 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 to 255	1	23	0001 0111
Issue of data (IOD)	8	0 to 255	1	80	0101 0000
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	–2.41 m	1111 1111 0000 1111
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.96 m/s	1111 1100 0100 0000
σ_{pr_gnd}	8	0 to 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 the bit scrambling (Note 2)	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 the bit scrambling (Note 3)	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	0 to 2	—	—	0	
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650100 12707716 71645524 74035772 26234621 45311123 22460075 52232477 16617052 04750422 07724363 40733535 05120746 45741125 22545252 73171513 51047466 13171745 10622642 17157064 67345046 36541025 07135576 55745512 222				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5 π/4 radians), relative to the phase of the first symbol.*

Table D-7A. Example of a Type 101 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3			E	100
Transmission length (bits)	17	0 to 1824 bits	1 bit	416	00000000110100000
Training sequence FEC	5				11011
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 101 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8,101	1	101	0110 0101
Message length	8	10 to 222 bytes	1 byte	46	0010 1110
Message (Type 101 example)					
Modified Z-count	14	0 to 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	1st of pair	01
Number of measurements	5	0 to 18	1	4	0 0100
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 × 10^{-3}m/m	5 × 10^{-6}m/m	0.115 × 10^{-3}m/m	0001 0111
Ephemeris CRC	16			0	0000 0000 0000 0000
Source availability duration	8	0 to 2540 s	10 s	Not provided	1111 1111
Number of B parameters	1	0 to 1	1	0	0
Spare	7			0	000 0000
Measurement Block 1					
Ranging source ID	8	1 to 255	1	2	0000 0010
Issue of data (IOD)	8	0 to 255	1	255	1111 1111
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+3.56 m	0000 0001 0110 0100
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.011 m/s	1111 1111 1111 0101
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	9.8 m	0011 0001
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Issue of data (IOD)	8	0 to 255	1	126	0111 1110
Pseudo-range 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	+0.002 m/s	0000 0000 0000 0010
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	3.4 m	0001 0001
Measurement Block 3					
Ranging source ID	8	1 to 255	1	12	0000 1100
Issue of data (IOD)	8	0 to 255	1	222	1101 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+4.11 m	0000 0001 1001 1011
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.029 m/s	1111 1111 1110 0011
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	10.2 m	0011 0011

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Measurement Block 4					
Ranging source ID	8	1 to 255	1	23	0001 0111
Issue of data (IOD)	8	0 to 255	1	80	0101 0000
Pseudo-range 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	-0.096 m/s	1111 1111 1010 0000
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	1.6 m	0000 1000
Message Block CRC	32				1000 1000 1001 1111 0111 1000 0000 0100
APPLICATION FEC	48				1100 1100 1110 0110 1111 0110 1100 1110 1101 0110 0110 0010
Input to the bit scrambling (Note 2)	0 41 60 1B 55 73 A4 A8 A6 74 17 C2 20 E8 00 00 FF 00 40 FF 26 80 AF FF 8C 20 7E 39 FF 40 00 88 30 7B D9 80 C7 FF CC E8 0A F0 FF 05 FF 10 20 1E F9 11 46 6B 73 6F 67 33				
Output from the bit scrambling (Note 3)	0 67 57 93 1F 6C BC 83 79 EE C2 1B 12 34 46 D0 09 C1 09 FC 3A 84 80 0F E6 9F 18 6D 77 8E 1E 60 19 1B BA FF BC AB 68 26 7B E7 BC CE FA 0B D3 C4 43 C8 E0 B6 FA 42 84 A1				
Fill bits	0 to 2			0	
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650105 06345463 57026113 51374661 15123376 12066670 44776307 04225000 02735027 73373152 13230100 04706272 74137202 47724524 12715704 15442724 01101677 44571303 66447212 222				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-8. Example of Type 1 and Type 2 VDB messages in a single burst

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	10 0
Transmission length (bits)	17	0 to 1 824 bits	1 bit	544	000 0000 1000 1000 00
Training sequence FEC	5	—	—	—	0000 0
APPLICATION DATA					
Message Block 1 (Type 1 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 1 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	2nd of pair	11
Number of measurements	5	0 to 18	1	1	0 0001
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 × 10^{-3} m/m	5 × 10^{-6} m/m	0 (SBAS)	0000 0000
Ephemeris CRC	16	—	—	0	0000 0000 0000 0000
Source availability duration	8	0 to 2 540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	122	0111 1010
Issue of data (IOD)	8	0 to 255	1	2	0000 0010
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 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 1 CRC	32	—	—	—	1011 0101 1101 0000 1011 1100 0101 0010
Message Block 2 (Type 2 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	34	0010 0010
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2	—	—	B	01
Spare	1	—	—	0	0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
GBAS continuity/integrity designator	3	0 to 7	1	1	001
Local magnetic variation	11	±180°	0.25°	58° E	000 1110 1000
Spare	5	—	—	0	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m	0	0000 0000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	45°40'32'' N	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	93°25'13''W	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid 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 to 48	1	5	0000 0101
Maximum Use Distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Message Block 2 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
Input to the bit scrambling (Note 2)	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 the bit scrambling (Note 3)	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 to 2	—	—	1	0
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650105 67443352 35201160 30501336 62023576 12066670 74007653 30010255 31031274 26172772 76236442 41177201 35131033 33421734 42751235 60342057 66270254 17431214 03421036 70316613 46567433 66547730 34732201 40607506 014444				

Notes.—
1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5 π/4 radians), relative to the phase of the first symbol.*

Table D-8A. Example of Type 1 and Type 2 VDB messages with additional data blocks 1 and 2

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3			E	100
Transmission length (bits)	17	0 to 1824 bits	1 bit	592	00000001001010000
Training sequence FEC	5				10110
APPLICATION DATA					
Message Block 1 (Type 1 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 1 example)					
Modified Z-count	14	0 to 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	2nd of pair	11
Number of measurements	5	0 to 18	1	1	0 0001
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275×10^{-3} m/m	5×10^{-6} m/m	0 (SBAS)	0000 0000
Ephemeris CRC	16			0	0000 0000 0000 0000
Source availability duration	8	0 to 2540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	122	0111 1010
Issue of data (IOD)	8	0 to 255	1	2	0000 0010
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+2.09 m	0000 0000 1101 0001
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 to 5.08 m	0.02 m	1.96 m	0110 0010
B1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block 1 CRC	32				00110010 10100100 11001011 00110000
Message Block 2 (Type 2 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	40	0010 1000
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2			B	01
Spare	1			0	0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
GBAS continuity/integrity designator	3	0 to 7	1	1	001
Local magnetic variation	11	±180°	0.25°	58° E	000 1110 1000
Spare	5			0	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 × 10^{-6}m/m	0.1 × 10^{-6}m/m	0	0000 0000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	45°40'32" N	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	93°25'13" W	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid 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 to 48	1	5	0000 0101
Maximum Use Distance (Dmax)	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Additional Data Blocks					
Additional Data Block Length	8	2 to 255	1	6	0000 0110
Additional Data Block Number	8	2 to 255	1	2	0000 0010
Additional Data Block 2					
Channel Number	16	20001 to 39999	1	25001	0110 0001 1010 1001
ΔLatitude	8	±25.4°	0.2°	5.2	0001 1010
ΔLongitude	8	±25.4°	0.2°	–3.4	1110 1111
Message Block 2 CRC	32				11100000 01110010 00011101 00100100
Application FEC	48				1110 0010 0101 1100 0000 1111 1010 1011 0011 0100 0100 0000
Input to the bit scrambling (Note 2)		0 42 90 0D 55 73 A4 A8 80 38 17 C3 80 00 00 00 FF 5E 40 8B 00 1C FF 46 40 C0 DF 01 0C D3 25 4C 55 73 A4 A8 40 14 A4 17 00 00 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 60 40 95 86 58 F7 24 B8 4E 07 02 2C D5 F0 3A 47			
Output from the bit scrambling (Note 3)		0 64 A7 85 1F 6C BC 83 5F A2 C2 1A B2 DC 46 D0 09 9F 09 88 1C 18 D0 B6 2A 7F B9 55 84 1D 3B A4 7C 13 C7 D7 3B 40 00 D9 71 17 DC 4B 2D 1B 7B 83 72 D4 F7 CA 62 C8 D9 12 25 5E 13 2E 13 E0 5A C0 CC 79 7A 5C A2 DD B9 75 B6 95 64 52 78 3F			
Fill bits	0 to 2			1	0
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 4)		00000035 11204546 31650107 56336574 60137224 74145772 26467132 56422234 30443700 05565722 06506741 73647332 27242654 63345227 31575333 33421734 42751235 60342057 66270254 17431214 03421036 70316613 46567433 62077121 37275607 55315167 17135031 34423411 274444			

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-8B. Example of a Type 2 message containing data blocks 1 and 4

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15	—	—	—	000 0000 0000 0000
Synchronization and ambiguity resolution	48	—	—	—	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier	3	—	—	E	100
Transmission length	17	0 to 1824 bits	1 bit	1704	0 0000 0110 1010 1000
Training sequence FEC	5	—	—	—	01000
APPLICATION DATA					
Message Block 1 (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 to 101	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	37	0010 0101
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2	—	—	B	01
Spare	1	—	—	—	0
GBAS continuity/integrity designator	3	0 to 7	1	2	010
Local magnetic variation	11	±180°	0.25°	E58.0°	000 1110 1000
Spare	5	—	—	—	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 x 10^{-6} m/m	0.1 x 10^{-6} m/m	4 x 10^{-6}	0010 1000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 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
Ellipsoid 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 to 48	1	5	0000 0101
Maximum use distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e\ C,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e\ C,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Additional Data Block 4					
Additional data block length	8	3	1 byte	3	0000 0011
Additional data block number	8	4	1	4	0000 0100
Slot group definition	8	—	—	E	0011 0000

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Message Block 1 CRC	32	—	—	—	1100 0101 1110 0000 0010 0110 1100 1011
Message Block 2 (Type 3 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	3	0000 0011
Message length	8	N/A	1 byte	170	1010 1010
Message (Type 3 example)					
Filler	1280	—	—	—	1010 1010 …... 1010 1010
Message Block 2 CRC	32	—	—	—	1001 0000 1110 1100 1101 1001 1011 1010
Application FEC	48	—	—	—	0000 1000 0010 0011 1100 1011 1101 0000 1101 0110 1011 0101
Input to the bit scrambling (Note 2)	0 45 58 02 55 30 CA 10 40 A4 A2 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C D3 64 07 A3 55 30 CA 10 C0 55 5D 9B 37 09 AD 6B 0B D3 C4 10				
Output from the bit scrambling (Note 3)	0 63 6F 8A 1F 2F D2 3B 9F 3E 77 CE 32 C8 D9 50 DE C1 C1 5A D4 09 7E E7 81 5A 5C D4 28 56 00 CE 29 60 A3 5F 77 87 C0 C9 D2 42 73 01 15 DB A6 8F EF 8C F3 88 DC 78 B6 C7 D0 93 58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7 17 2D AD F4 0B 29 82 04 61 96 E4 50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF 60 8D 18 75 B9 2B C5 FC 94 C8 57 79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91 9B A4 43 E9 63 05 1D 95 B4 54 29 56 05 51 95 5B AA BC 00 36 66 2E EE 0F 0E 72 71 21 25 E5 EB 14 FD A8 CB F8 83 38 62 39 1E 3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3 78 1D 39 B5 C4 2B 69 FD 04 CA 68 81 07 9A 64 8F 6B 39 7D 2A 34 D0 6F EA				
Fill bits	0 to 2	—	—	2	00
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650102 46331130 13067746 52605627 35467122 62533573 77100603 75554273 01666461 41203311 42111340 14733657 27302663 77076361 44301001 17175104 35263707 43007132 40135774 07012022 52546153 57425454 25413051 54022547 01622754 12302141 24615265 50476225 56622615 23311312 51275055 11132570 45242065 63665236 04052447 35155017 73303745 61650521 06765616 04756006 16264736 30530735 02426407 53610061 12111501 04147002 72512117 74672621 42254251 12533720 37475054 44460104 57516674 46523401 22503075 25125742 03431633 22607072 37230050 35463673 43300570 12353363 77140357 42715724 03470633 30354042 67720645 27225703 50111005 40736127 14021742 36572477 13042222 2				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-9. Example of a Type 4 message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				010 0011 1110 1111 1100 0110 0011 1011 0000 0011 1100 1000 0
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	D	01 1
Transmission length (bits)	17	0 to 1 824 bits	1 bit	784	000 0000 1100 0100 00
Training sequence FEC	5	—	—	—	0000 0
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 4 message)					
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 to 8	1	4	0000 0100
Message length	8	10 to 222 bytes	1 byte	92	0101 1100
Message (Type 4 example)					
FAS Data Set 1					
Data set length	8	2 to 212	1 byte	41	0010 1001
FAS Data Block 1					
Operation type	4	0 to 15	1	0	0000
SBAS service provider	4	0 to 15	1	15	1111
Airport ID	32	—	—	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway number	6	0 to 36	1	15	00 1111
Runway letter	2	—	—	R	01
Approach performance designator	3	0 to 7	1	CAT 1	001
Route indicator	5	—	—	C	0001 1
Reference path data selector (RPDS)	8	0 to 48	1	3	0000 0011
Reference path identifier	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°E	0000 0000 1001 0011 1101 1110 1001 0000
LTP/FTP height	16	–512.0 to 6 041.5 m	0.1 m	197.3	0001 1011 1011 0101
∆FPAP latitude	24	±1°	0.0005 arcsec	–0.025145°	1111 1101 0011 1100 1100 1100
∆FPAP longitude	24	±1°	0.0005 arcsec	0.026175°	0000 0010 1110 0000 0010 1100
Approach threshold crossing height (TCH)	15	0 to 1 638.35 m (0 to 3 276.7 ft)	0.05 m (0.1 ft)	17.05 m	000 0001 0101 0101
Approach TCH units selector	1	0 = ft; 1 = m	—	metres	1
Glide path angle (GPA)	16	0 to 90°	0.01°	3°	0000 0001 0010 1100
Course width	8	80.0 to 143.75 m	0.25 m	105	0110 0100
∆Length offset	8	0 to 2 032 m	8 m	0	0000 0000
FAS Data Block 1 CRC	32	—	—	—	1010 0010 1010 0101 1010 1000 0100 1101
FASVAL/Approach status	8	0 to 25.4	0.1 m	10	0110 0100
FASLAL/Approach status	8	0 to 50.8	0.2 m	40	1100 1000
FAS Data Set 2					
Data set length	8	2 to 212	1 byte	41	0010 1001

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
FAS Data Block 2					
Operation type	4	0 to 15	1	0	0000
SBAS service provider	4	0 to 15	1	01	0001
Airport ID	32	—	—	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway number	6	0 to 36	1	33	10 0001
Runway letter	2	—	—	R	01
Approach performance designator	3	0 to 7	1	CAT 1	001
Route indicator	5	—	—	A	0000 1
Reference path data selector (RPDS)	8	0 to 48	1	21	0001 0101
Reference path identifier	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 to 6 041.5 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 to 1 638.35 m (0 to 3 276.7 ft)	0.05 m (0.1 ft)	15.25 m	000 0001 0011 0001
Approach TCH units selector	1	0 = ft; 1 = m	—	metres	1
Glide path angle (GPA)	16	0 to 90°	0.01°	3.01°	0000 0001 0010 1101
Course width	8	80.0 to 143.75 m	0.25 m	105	0110 0100
ΔLength offset	8	0 to 2 032 m	8 m	0	0000 0000
FAS data block 2 CRC	32	—	—	—	1010 1111 0100 1101 1010 0000 1101 0111
FASVAL/Approach status	8	0 to 25.4	0.1 m	10	0110 0100
FASLAL /Approach status	8	0 to 50.8	0.2 m	40	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
Input to the bit scrambling (Note 2)	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 the bit scrambling (Note 3)	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 to 2	—	—	1	0
Power ramp down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	0000003511204546316504322300771662170713052556673176724345377776157763461661570543615214576405133401677 5214231304443061301150266774341755603276241630527536540015247051420322575333462555437707605652760631444 6243163101353722250120760407526435103457714077770415665273600122324007402031443362754444				

Notes.—
1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-10. Example of a Type 5 message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	D	01 1
Transmission length (bits)	17	0 to 1 824 bits	1 bit	272	000 0000 0100 0100 00
Training sequence FEC	5	—	—	—	0001 1
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 5 message)					
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 to 8	1	5	0000 0101
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 5 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Spare	2	—	—	—	00
Number of impacted sources (N)	8	0 to 31	1	2	0000 0010
First impacted source					
Ranging source ID	8	1 to 255	1	4	0000 0100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	50 s	0000 101
Second impacted source					
Ranging source ID	8	1 to 255	1	3	0000 0011
Source availability sense	1	—	—	Will start	1
Source availability duration	7	0 to 1 270 s	10 s	200 s	0010 100
Number of obstructed approaches (A)	8	0 to 255	1	2	0000 0010
First obstructed approach					
Reference path data selector (RPDS)	8	0 to 48	1	21	0001 0101
Number of impacted sources for first obstructed approach (N_A)	8	1 to 31	1	2	0000 0010
First impacted ranging source of first obstructed approach					
Ranging source ID	8	1 to 255	1	12	0000 1100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	250 s	0011 001
Second impacted ranging source of first obstructed approach					
Ranging source ID	8	1 to 255	1	14	0000 1110
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	1 000 s	1100 100
Second obstructed approach					
Reference path data selector (RPDS)	8	0 to 48	1	14	0000 1110
Number of impacted sources for second obstructed approach (N_A)	8	1 to 31	1	1	0000 0001

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
First impacted ranging source of second obstructed approach					
Ranging source ID	8	1 to 255	1	12	0000 1100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	220 s	0010 110
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 the bit scrambling (Note 2)	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 the 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 to 2	—	—	0	
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 3)	00000035112045463165043220566605510676024161244773634632207001032240066013321241662311636437771101731157430232344514664444 4				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians) relative to the first symbol.*

7.18 Type 101 message

Type 101 message is an alternative to Type 1 message developed to fit the specific needs of GRAS systems. The primary difference in the contents and application of these two message types is two-fold: (a) Type 101 message has a larger available range for σpr_gnd values and (b) ground subsystem time-to-alert is larger for a system broadcasting Type 101 messages. The first condition would typically occur in a system where a broadcast station covers a large area, such that decorrelation errors increase the upper limit of the pseudo-range correction errors. The second condition may be typical for systems where a central master station processes data from multiple receivers dispersed over a large area.

8. Signal quality monitor (SQM) design

8.1 The objective of the signal quality monitor (SQM) is to detect satellite signal anomalies in order to prevent aircraft receivers from using misleading information (MI). MI is an undetected aircraft pseudo-range differential error greater than the maximum error (MERR) that can be tolerated. These large pseudo-range errors are due to C/A code correlation peak distortion caused by satellite payload failures. If the reference receiver used to create the differential corrections and the aircraft receiver have different measurement mechanizations (i.e. receiver bandwidth and tracking loop correlator spacing), the signal distortion affects them differently. The SQM must protect the aircraft receiver in cases when mechanizations are not similar. SQM performance is further defined by the probability of detecting a satellite failure and the probability of incorrectly annunciating a satellite failure.

8.2 The signal effects that might cause a GBAS or SBAS to output MI can be categorized into three different effects on the correlation function as follows:

a) *Dead zones:* If the correlation function loses its peak, the receiver's discriminator function will include a flat spot or dead zone. If the reference receiver and aircraft receiver settle in different portions of this dead zone, MI can result.

b) *False peaks:* If the reference receiver and aircraft receiver lock to different peaks, MI could exist.

c) *Distortions:* If the correlation peak is misshapen, an aircraft that uses a correlator spacing other than the one used by the reference receivers may experience MI.

8.3 The threat model proposed for use in assessment of SQM has three parts that can create the three correlation peak pathologies listed above.

8.4 Threat Model A consists of the normal C/A code signal except that all the positive chips have a falling edge that leads or lags relative to the correct end-time for that chip. This threat model is associated with a failure in the navigation data unit (NDU), the digital partition of a GPS or GLONASS satellite.

8.4.1 Threat Model A for GPS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in fractions of a chip. The range for this parameter is $-0.12 \leq \Delta \leq 0.12$. Threat Model A for GLONASS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in fractions of a chip. The range for this parameter is $-0.11 \leq \Delta \leq 0.11$.

8.4.2 Within this range, threat Model A generates the dead zones described above. (Waveforms with lead need not be tested, because their correlation functions are simply advances of the correlation functions for lag; hence, the MI threat is identical.)

8.5 Threat Model B introduces amplitude modulation and models degradations in the analog section of the GPS or GLONASS satellite. More specifically, it consists of the output from a second order system when the nominal C/A code baseband signal is the input. Threat Model B assumes that the degraded satellite subsystem can be described as a linear system dominated by a pair of complex conjugate poles. These poles are located at $\sigma \pm j2\pi f_d$, where σ is the damping factor in 10^6 nepers/second and f_d is the resonant frequency with units of 10^6 cycles/second.

8.5.1 The unit step response of a second order system is given by:

$$e(t) = \begin{Bmatrix} 0 & t \le 0 \\ 1 - \exp(-\sigma t)\left[\cos\omega_d t + \dfrac{\sigma}{\omega_d}\sin\omega_d t\right] & t \ge 0 \end{Bmatrix}$$

where $\omega_d = 2\pi f_d$.

8.5.2 Threat Model B for GPS corresponding to second order anomalies uses the following ranges for the parameters Δ, f_d and σ:

$$\Delta = 0;\ 4 \le f_d \le 17;\ \text{and } 0.8 \le \sigma \le 8.8.$$

Threat Model B for GLONASS corresponding to second order anomalies uses the following ranges for the parameters defined above:

$$\Delta = 0;\ 10 \le f_d \le 20;\ \text{and } 2 \le \sigma \le 8.$$

8.5.3 Within these parameter ranges, threat Model B generates distortions of the correlation peak as well as false peaks.

8.6 Threat Model C introduces both lead/lag and amplitude modulation. Specifically, it consists of outputs from a second order system when the C/A code signal at the input suffers from lead or lag. This waveform is a combination of the two effects described above.

8.6.1 Threat Model C for GPS includes parameters Δ, f_d and σ with the following ranges:

$$-0.12 \le \Delta \le 0.12;\ 7.3 \le f_d \le 13;\ \text{and } 0.8 \le \sigma \le 8.8.$$

Threat Model C for GLONASS includes parameters Δ, f_d and σ with the following ranges:

$$-0.11 \le \Delta \le 0.11;\ 10 \le f_d \le 20;\ \text{and } 2 \le \sigma \le 8.$$

8.6.2 Within these parameter ranges, threat Model C generates dead zones, distortions of the correlation peak and false peaks.

8.7 Unlike GPS and GLONASS, the SBAS signal is commissioned and controlled by the service provider. Moreover, the service provider also monitors the quality of the signal from the SBAS. To this end, the threat model will be specified and published by the service provider for each SBAS satellite. The SBAS SQM will be designed to protect all avionics that comply with Table D-12. Publication of the threat model is required for those cases where a service provider chooses to allow the SBAS ranging signal from a neighbouring service provider to be used for precision approach by SBAS or GBAS. In these cases, the service provider will monitor the SBAS ranging signal from the neighbouring satellite.

8.8 In order to analyse the performance of a particular monitor design, the monitor limit must be defined and set to protect individual satellite pseudo-range error relative to the protection level, with an allocation of the ground subsystem integrity risk. The maximum tolerable error (denoted as MERR) for each ranging source *i* can be defined in GBAS as:

$$\text{MERR} = K_{ffmd}\sigma_{pr\_gnd,i} \text{ and}$$

$$\text{MERR}=K_{V,PA}\sqrt{\sigma^2_{i,UDRE} + \min\{\sigma^2_{i,UIRE}\}}$$

for SBAS APV and precision approach where $\min\{\sigma^2_{i,UIRE}\}$ is the minimum possible value for any user. MERR is evaluated at the output of a fault-free user receiver and varies with satellite elevation angle and ground subsystem performance.

8.9 The SQM is designed to limit the UDRE to values below the MERR in the case of a satellite anomaly. Typically, the SQM measures various correlation peak values and generates spacing and ratio metrics that characterize correlation peak distortion. Figure D-9 illustrates typical points at the top of a fault-free, unfiltered correlation peak.

8.9.1 A correlator pair is used for tracking. All other correlator values are measured with respect to this tracking pair.

8.9.2 Two types of test metrics are formed: early-minus-late metrics (D) that are indicative of tracking errors caused by peak distortion, and amplitude ratio metrics (R) that measure slope and are indicative of peak flatness or close-in, multiple peaks.

8.9.3 It is necessary that the SQM has a precorrelation bandwidth that is sufficiently wide to measure the narrow spacing metrics, so as not to cause significant peak distortion itself and not to mask the anomalies caused by the satellite failure. Typically, the SQM receiver must have a precorrelation bandwidth of at least 16 MHz for GPS and at least 15 MHz for GLONASS.

8.9.4 The test metrics are smoothed using low-pass digital filters. The time constant of these filters are to be shorter than those used jointly (and standardized at 100 seconds) by the reference receivers for deriving differential corrections and by the aircraft receiver for smoothing pseudo-range measurements (using carrier smoothing). The smooth metrics are then compared to thresholds. If any one of the thresholds is exceeded, an alarm is generated for that satellite.

8.9.5 The thresholds used to derive performance are defined as minimum detectable errors (MDEs) and minimum detectable ratios (MDRs). Fault-free false detection probability and missed detection probability are used to derive MDEs and MDRs. The noise in metrics (D) and (R), as denoted $\sigma_{D,test}$ and $\sigma_{R,test}$ below, is dominated by multipath errors. Note that the metric test can also have a mean value (μ_{test}) caused by SQM receiver filter distortion. Threshold tests must also account for the mean values.

8.9.6 The MDE and MDR values used in the SQM performance simulations are calculated based on the following equations:

$$MDE = (K_{ffd} + K_{md})\,\sigma_{D,test} \text{ and}$$
$$MDR = (K_{ffd} + K_{md})\,\sigma_{R,test}$$

where

$K_{ffd} = 5.26$ is a typical fault-free detection multiplier representing a false detection probability of 1.5×10^{-7} per test;

$K_{md} = 3.09$ is a typical missed detection multiplier representing a missed detection probability of 10^{-3} per test;

$\sigma_{D,test}$ is the standard deviation of measured values of difference test metric D; and

$\sigma_{R,test}$ is the standard deviation of measured values of ratio test metric R.

8.9.7 If multiple independent SQM receivers are used to detect the failures, the sigma values can be reduced by the square root of the number of independent monitors.

8.9.8 A failure is declared if

$$|\, D,test - \mu_{D,test} \,| \geq MDE \text{ or}$$
$$|\, R,test - \mu_{R,test} \,| \geq MDR$$

for any of the tests performed, where $\mu_{X,test}$ is the mean value of the test X that accounts for fault-free SQM receiver filter distortion, as well as correlation peak distortion peculiar to the specific C/A code PRN. (Not all C/A code correlation peaks have the same slope. In a simulation environment, however, this PRN distortion can be ignored, and a perfect correlation peak can be used, except for simulated filter distortion.)

8.10 The standard deviations of the test statistics, $\sigma_{D,test}$ and $\sigma_{R,test}$ can be determined via data collection on a multicorrelator receiver in the expected operating environment. The data collection receiver utilizes a single tracking pair of correlators and additional correlation function measurement points which are slaved to this tracking pair, as illustrated in Figure D-9. Data is collected and smoothed for all available measurement points in order to compute the metrics. The standard deviation of these metrics define $\sigma_{D,test}$. It is also possible to compute these one sigma test statistics if a multipath model of the installation environment is available.

8.10.1 The resulting $\sigma_{D,test}$ is highly dependent on the multipath environment in which the data are collected. The deviation due to multipath can be an order of magnitude greater than that which would result from noise even at minimum carrier-to-noise level. This aspect illustrates the importance of the antenna design and siting criteria which are the primary factors in determining the level of multipath that will enter the receiver. Reducing multipath will significantly decrease the resulting MDEs and thus improve the SQM capabilities.

8.10.2 Mean values $\mu_{D,test}$ and $\mu_{R,test}$, on the other hand, are determined in a relatively error-free environment, such as through the use of GPS and GLONASS signal simulator as input. These mean values model the nominal SQM receiver's filter distortion of the autocorrelation peak, including the effects of distortion due to adjacent minor autocorrelation peaks. The mean values can differ for the various PRNs based on these properties.

8.10.3 The presence of nominal signal deformation biases may cause the distribution of the monitor detectors to have non-zero mean. These biases can be observed by averaging measurements taken from a real-world data collection. Note that the nominal biases may depend on elevation and they typically change slowly over time.

8.11 In order for the ground monitor to protect users against the different threat models described above, it is necessary to assume that aircraft receivers have specific characteristics. If no such constraints were assumed, the complexity of the ground monitor would be unnecessarily high. Evolution in the technology may lead to improved detection capability in the aircraft receiver and may alleviate the current constraints.

8.11.1 For double-delta correlators, the aircraft receiver tracks the strongest correlation peak over the full code sequence for every ranging source used in the navigation solution.

8.11.2 For double-delta correlators, the precorrelation filter rolls off by at least 30 dB per octave in the transition band. For GBAS receivers, the resulting attenuation in the stop band is required to be greater than or equal to 50 dB (relative to the peak gain in the pass band).

8.11.3 The following parameters are used to describe the tracking performance specific to each type of satellite:

a) the instantaneous correlator spacing is defined as the spacing between a particular set of early and late samples of the correlation function;

b) the average correlator spacing is defined as a one-second average of the instantaneous correlator spacing. The average applies over any one-second time frame;

c) the discriminator Δ is based upon an average of early-minus-late samples with spacings inside the specified range, or is of the type $\Delta = 2\Delta_{d1} - \Delta_{2d1}$, with both d_1 and $2d_1$ in the specified range. Either a coherent or non-coherent discriminator is used;

d) the differential group delay applies to the entire aircraft system prior to the correlator, including the antenna. The differential group delay is defined as:

$$\left|\frac{d\phi}{d\omega}(f_c) - \frac{d\phi}{d\omega}(f)\right|$$

where

f_c is the precorrelation band pass filter centre frequency;

f is any frequency within the 3dB bandwidth of the precorrelation filter;

ϕ is the combined phase response of precorrelation band pass filter and antenna; and

ω is equal to $2\pi f$.

8.11.4 For aircraft receivers using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11.

8.11.5 For aircraft receivers using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12.

8.11.6 For aircraft receivers using double-delta correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Tables D-13A and D-13B.

8.11.7 For aircraft receivers using the early-late or double-delta correlators and tracking SBAS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14.

9. Status monitoring and NOTAM

9.1 System status

9.1.1 Degradation of GBAS usually has local effects and affects mainly approach operations. System degradation of GBAS is to be distributed as approach-related information.

9.1.2 Degradation of core satellite constellation(s) or SBAS usually has not only local effects, but additional consequences for a wider area, and may directly affect en-route operations. System degradation of these elements is to be distributed as area-related information. An example is a satellite failure.

9.1.3 Degradation of GRAS may have local effects and/or wide area effects. Therefore, if the degradation has only local effects, GRAS system degradation information is to be distributed in accordance with 9.1.1. If the degradation has wide area effects, GRAS system degradation information is to be distributed in accordance with 9.1.2.

9.1.4 Information is to be distributed to indicate the inability of GNSS to support a defined operation. For example, GPS/SBAS may not support a precision approach operation on a particular approach. This information can be generated automatically or manually based upon models of system performance.

Table D-11. GPS tracking constraints for early-late correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	2 < BW ≤ 7 MHz	0.045 – 1.1	0.04 – 1.2	≤ 600 ns
2	7 < BW ≤ 16 MHz	0.045 – 0.21	0.04 – 0.235	≤ 150 ns
3	16 < BW ≤ 20 MHz	0.045 – 0.12	0.04 – 0.15	≤ 150 ns
4	20 < BW ≤ 24 MHz	0.08 – 0.12	0.07 – 0.13	≤ 150 ns

Table D-12. GLONASS tracking constraints for early-late correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing range (chips)	Instantaneous correlator spacing range (chips)	Differential group delay
1	7 < BW ≤ 9 MHz	0.05 – 1.0	0.045 – 1.1	≤100 ns
2	9 < BW ≤ 15 MHz	0.05 – 0.2	0.045 – 0.22	≤ 100 ns
3	15 < BW ≤ 18 MHz	0.05 – 0.1	0.045 – 0.11	≤ 100 ns

Table D-13A. GPS tracking constraints for GRAS and SBAS airborne receivers with double-delta correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (X) (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	(–50 × X) + 12 < BW ≤ 7 MHz	0.1 – 0.2	0.09 – 0.22	≤ 600 ns
	2 < BW ≤ 7 MHz	0.2 – 0.6	0.18 – 0.65	
2	(–50 × X) + 12 < BW ≤ (40 × X) + 11.2 MHz	0.045 – 0.07	0.04 – 0.077	≤ 150 ns
	(–50 × X) + 12 < BW ≤ 14 MHz	0.07 – 0.1	0.062 – 0.11	
	7 < BW ≤ 14 MHz	0.1 – 0.24	0.09 – 0.26	
3	14 < BW ≤ 16 MHz	0.07 – 0.24	0.06 – 0.26	≤ 150 ns

Table D-13B. GPS tracking constraints for GBAS airborne receivers with double-delta correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing range (X) (chips)	Instantaneous correlator spacing range (chips)	Differential group delay
1	(–50 × X) + 12 < BW ≤ 7 MHz	0.1 – 0.2	0.09 – 0.22	≤ 600 ns
	2 < BW ≤ 7 MHz	0.2 – 0.6	0.18 – 0.65	
2	(–50 × X) + 12 < BW ≤ (133.33 × X) + 2.667 MHz	0.07 – 0.085	0.063 – 0.094	≤ 150 ns
	(–50 × X) + 12 < BW ≤ 14 MHz	0.085 – 0.1	0.077 – 0.11	
	7 < BW ≤ 14 MHz	0.1 – 0.24	0.09 – 0.26	
3	14 < BW ≤ 16 MHz	0.1 – 0.24	0.09 – 0.26	≤ 150 ns
	(133.33 × X) + 2.667 < BW ≤ 16 MHz	0.085 – 0.1	0.077 – 0.11	

Table D-14. SBAS ranging function tracking constraints

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	2 < BW ≤ 7 MHz	0.045 – 1.1	0.04 – 1.2	≤ 600 ns
2	7 < BW ≤ 20 MHz	0.045 – 1.1	0.04 – 1.2	≤ 150 ns

9.2 Information on type of degradation

The following information is to be distributed:

a) non-availability of service;

b) downgrade of service, if applicable; and

c) time and expected duration of degradation.

9.3 Timing of notification

For scheduled events, notification should be given to the NOTAM authority at least 72 hours prior to the event. For unscheduled events, notification to the NOTAM authority should be given within 15 minutes. Notification should be given for events of 15-minute, or longer, duration.

10. Interference

10.1 Potential for interference

Satellite radio navigation systems such as GPS and GLONASS feature relatively weak received signal power, meaning that an interference signal could cause loss of service. In order to maintain service, it will be necessary to ensure that the maximum interference levels specified in the SARPs are not exceeded.

10.2 Specification of the interference threshold at the antenna port

The indications of the interference threshold levels are referenced to the antenna port. In this context, the term “antenna port” means the interface between the antenna and the GNSS receiver where the satellite signal power corresponds to the nominal minimum received signal power of –164.5 dBW for GPS and –165.5 dBW for GLONASS. Due to the reduced distance from potential interference sources, GNSS receivers that are used for the approach phase of flight must have a higher interference threshold than receivers that are only used for en-route navigation.

10.3 In-band interference sources

A potential source of in-band harmful interference is Fixed Service operation in certain States. There is a primary allocation to the fixed service for point-to-point microwave links in certain States in the frequency band used by GPS and GLONASS.

10.4 Out-of-band interference sources

Potential sources of out-of-band interference include harmonics and spurious emissions of aeronautical VHF and UHF transmitters. Out-of-band noise, discrete spurious products and intermodulation products from radio and TV broadcasts can also cause interference problems.

10.5 Aircraft generated sources

10.5.1 The potential for harmful interference to GPS and GLONASS on an aircraft depends on the type of aircraft, its size and the transmitting equipment installed. The GNSS antenna location should take into account the possibility of on-board interference (mainly SATCOM).

10.5.2 GNSS receivers that are used on board aircraft with SATCOM equipment must have a higher interference threshold in the frequency range between 1 610 MHz and 1 626.5 MHz than receivers on board aircraft without SATCOM equipment. Therefore, specifications for the interference threshold discriminate between both cases.

Note.— Limits for radiated SATCOM aircraft earth stations are given in Annex 10, Volume III, Part I, Chapter 4, 4.2.3.5.

10.5.3 The principal mitigation techniques for on-board interference include shielding, filtering, receiver design techniques, and, especially on larger aircraft, physical separation of antennas, transmitters and cabling. Receiver design techniques include the use of adaptive filters and interference cancellation techniques that mitigate against narrow in-band interference. Antenna design techniques include adaptive null steering antennas that reduce the antenna gain in the direction of interference sources without reducing the signal power from satellites.

10.6 Integrity in the presence of interference

The requirement that SBAS and GBAS receivers do not output misleading information in the presence of interference is intended to prevent the output of misleading information under unintentional interference scenarios that could arise. It is not intended to specifically address intentional interference. While it is impossible to completely verify this requirement through testing, an acceptable means of compliance can be found in the appropriate receiver Minimum Operational Performance Standards published by RTCA and EUROCAE.

11. Recording of GNSS parameters

11.1 In order to be able to conduct post-incident/accident investigations (Chapter 2, 2.1.4.2 and 2.1.4.3), it is necessary to record GNSS information both for the augmentation system and for the appropriate GNSS core system constellation used for the operation. The parameters to be recorded are dependent on the type of operation, augmentation system and core elements used. All parameters available to users within a given service area should be recorded at representative locations in the service area.

11.2 The objective is not to provide independent assurance that the GNSS is functioning correctly, nor is it to provide another level of system monitoring for anomalous performance or input data for a NOTAM process. The recording system need not be independent of the GNSS service and may be delegated to other States or entities. In order to enable future reconstruction of position, velocity and time indications provided by specific GNSS configurations, it is recommended to log data continuously, generally at a 1 Hz rate.

11.3 For GNSS core systems the following monitored items should be recorded for all satellites in view:

a) observed satellite carrier-to-noise density (C/N_0);

b) observed satellite raw pseudo-range code and carrier phase measurements;

c) broadcast satellite navigation messages, for all satellites in view; and

d) relevant recording receiver status information.

11.4 For SBAS the following monitored items should be recorded for all geostationary satellites in view in addition to the GNSS core system monitored items listed above:

a) observed geostationary satellite carrier-to-noise density (C/N_0);

b) observed geostationary satellite raw pseudo-range code and carrier phase measurements;

c) broadcast SBAS data messages; and

d) relevant receiver status information.

11.5 For GBAS the following monitored items should be recorded in addition to the GNSS core system and SBAS monitored items listed above (where appropriate):

a) VDB power level;

b) VDB status information; and

c) broadcast GBAS data messages.

12. GNSS performance assessment

The data described in Section 11 may also support periodic confirmation of GNSS performance in the service area.

13. GNSS and database

Note.— Provisions relating to aeronautical data are contained in Annex 11, Chapter 2, and Annex 15, Chapter 3.

13.1 The database is to be current with respect to the effective AIRAC cycle, which generally means that a current database be loaded into the system approximately every 28 days. Operating with out-of-date navigation databases has to be avoided.

13.2 In certain situations, operations using an expired database can be conducted safely by implementing a process and/or using procedures to ensure that the required data is correct. These processes and/or procedures need prior approval by the State.

13.2.1 These procedures should be based on one of the following methods:

a) require the crew to check, prior to the operation, critical database information against current published information. (This method increases workload and would not be practical for all applications.); or

b) waive the requirement for a current database and frequent checks by the crew of the database information. This waiver can only be applied to very specific cases where aircraft are operated in a strictly limited geographical area and where that area is controlled by a single regulatory agency or multiple agencies that coordinate this process; or

c) use another approved method that ensures an equivalent level of safety.

14. Modelling of residual errors

14.1 Application of the integrity requirements for SBAS and GBAS requires that a model distribution be used to characterize the error characteristics in the pseudo-range. The HPL/LPL and VPL models (see 7.5.3) are constructed based on models of the individual error components (in the pseudo-range domain) that are independent, zero-mean, normal distributions. The relationship between this model and the true error distribution must be defined.

14.2 One method of ensuring that the protection level risk requirements are met is to define the model variance (σ^2), such that the cumulative error distribution satisfies the conditions:

$$\int_{y}^{\infty} f(x)dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \ge 0 \text{ and}$$

$$\int_{-\infty}^{-y} f(x)dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \ge 0 \text{ and}$$

where

f(x) = probability density function of the residual aircraft pseudo-range error; and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}} dt.$$

14.3 This method can be directly applied when the error components have zero-mean, symmetrical and unimodal probability density functions. This is the case for the receiver contribution to corrected pseudo-range error, since the aircraft element is not subjected to low-frequency residual multipath errors.

14.4 This method can be extended to address non-zero-mean, residual errors by inflating the model variance to compensate for the possible effect of the mean in the position domain.

14.5 Verification of the pseudo-range error models must consider a number of factors including:

a) the nature of the error components;

b) the sample size required for confidence in the data collection and estimation of each distribution;

c) the correlation time of the errors; and

d) the sensitivity of each distribution to geographic location and time.

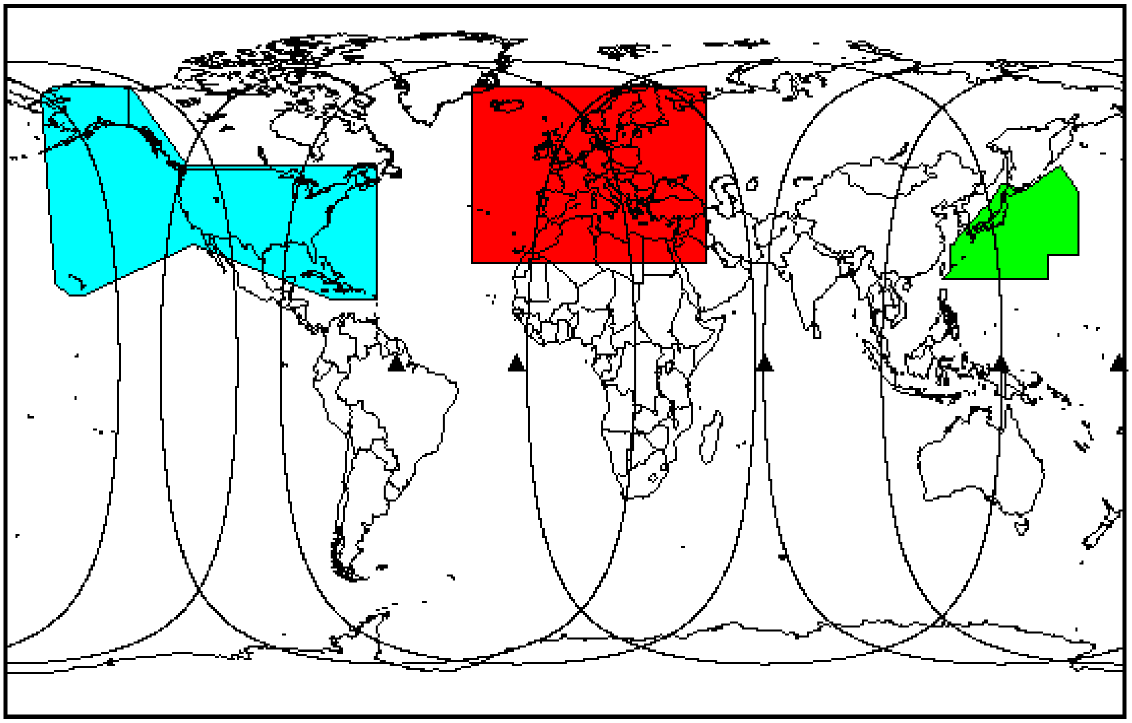
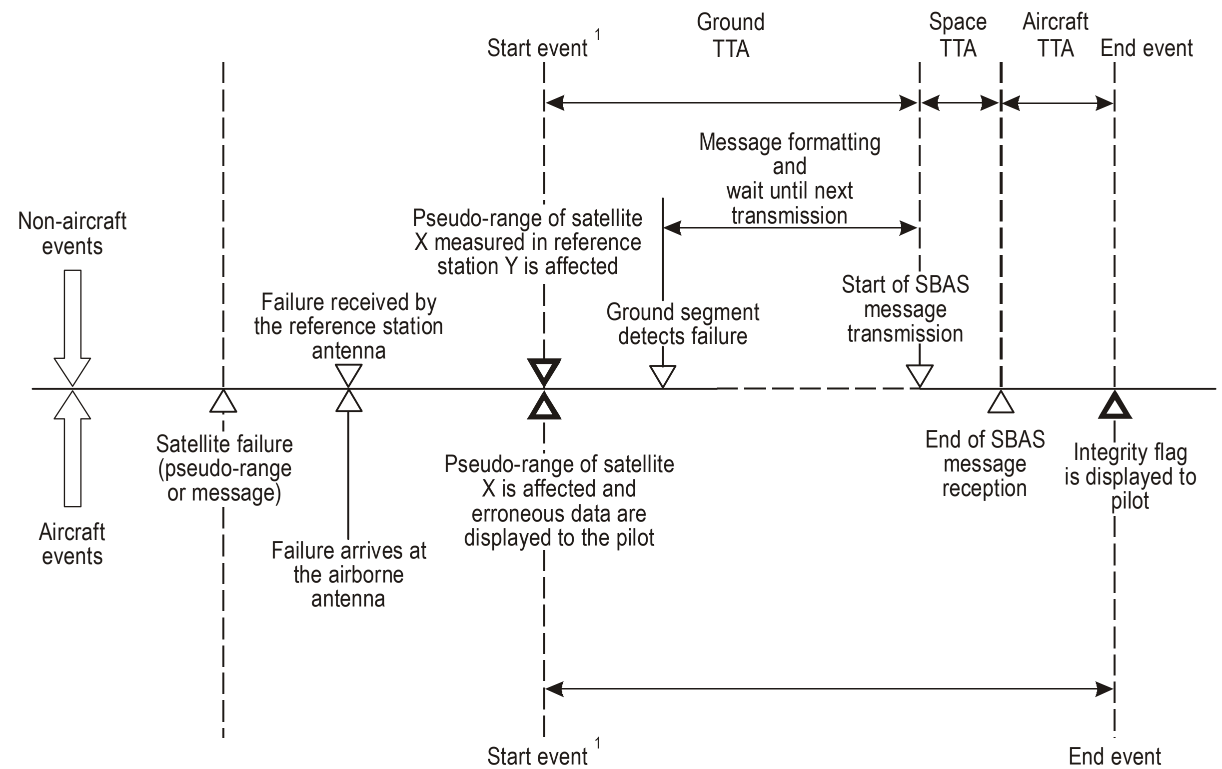


Figure D-1. Initial SBAS coverage areas and service areas



[1] Both events are considered as simultaneous. This is not strictly the case because of difference of performance between specific receivers. There is a slight difference due to receiver processing between the time the pseudo-range measurement is affected and the erroneous data are displayed. For practical reasons, this is not reflected in this diagram.

Figure D-2. SBAS time-to-alert

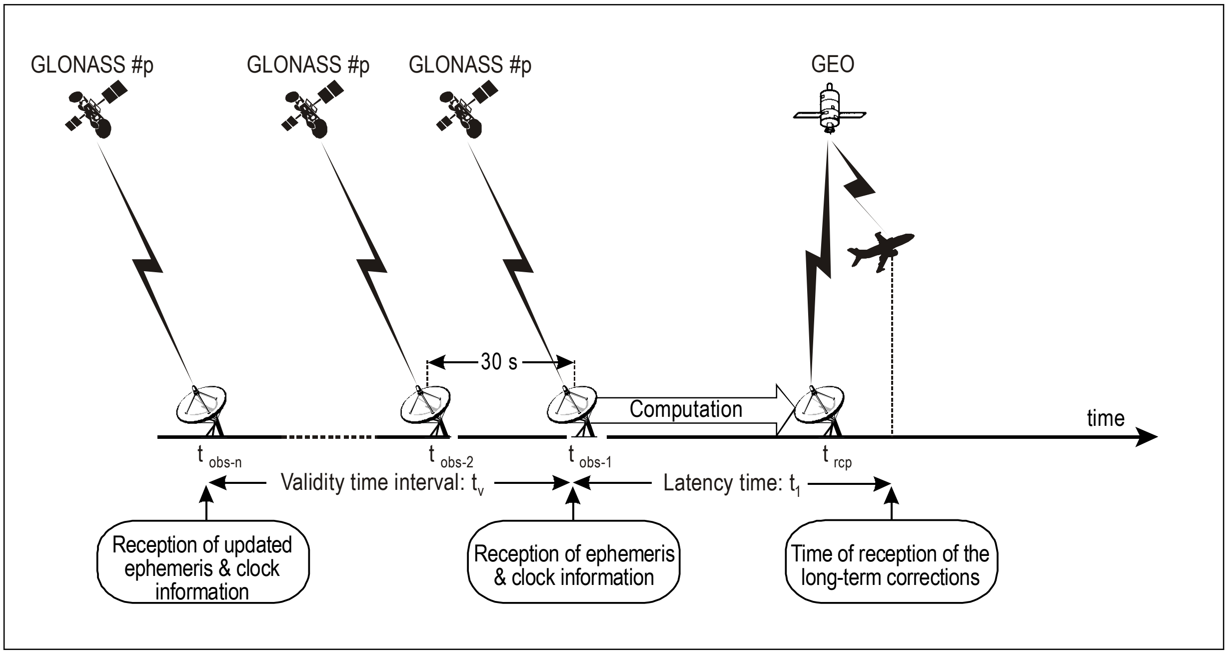
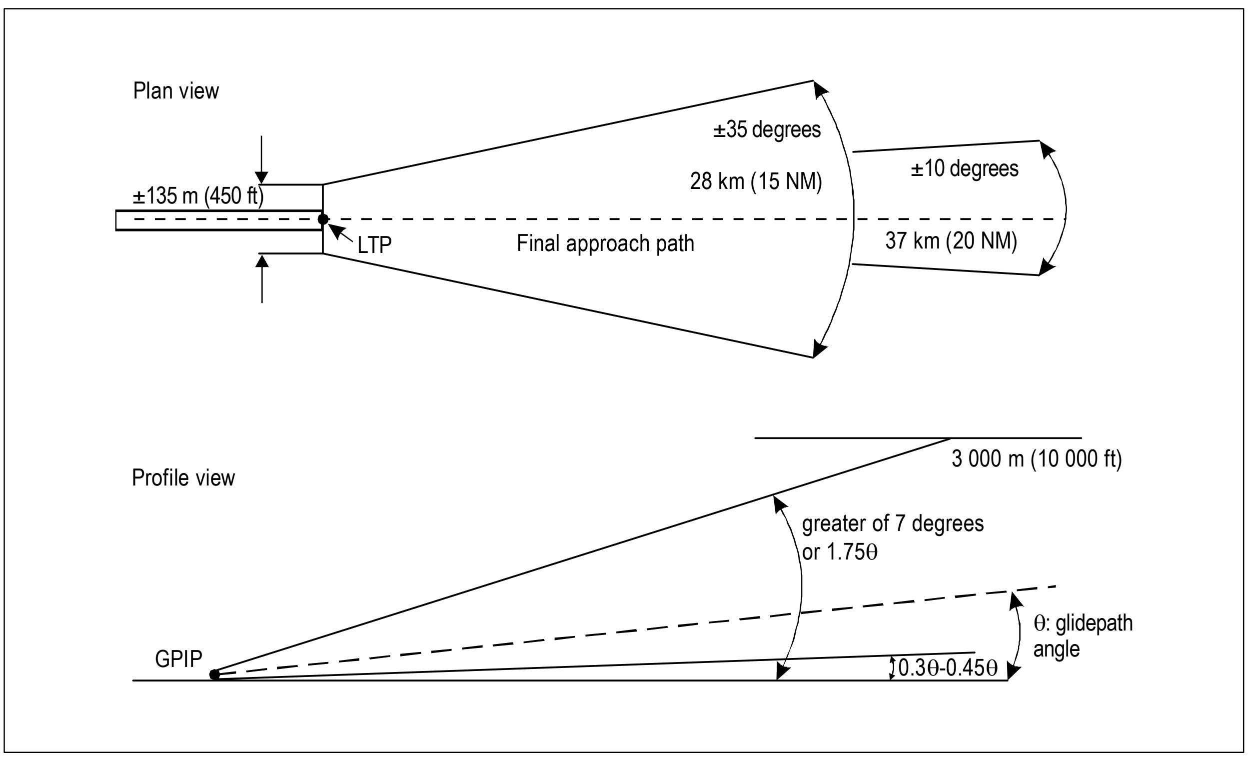


Figure D-3. GLONASS time



GPIP — glide path intersection point
LTP — landing threshold point

Figure D-4. Minimum GBAS coverage

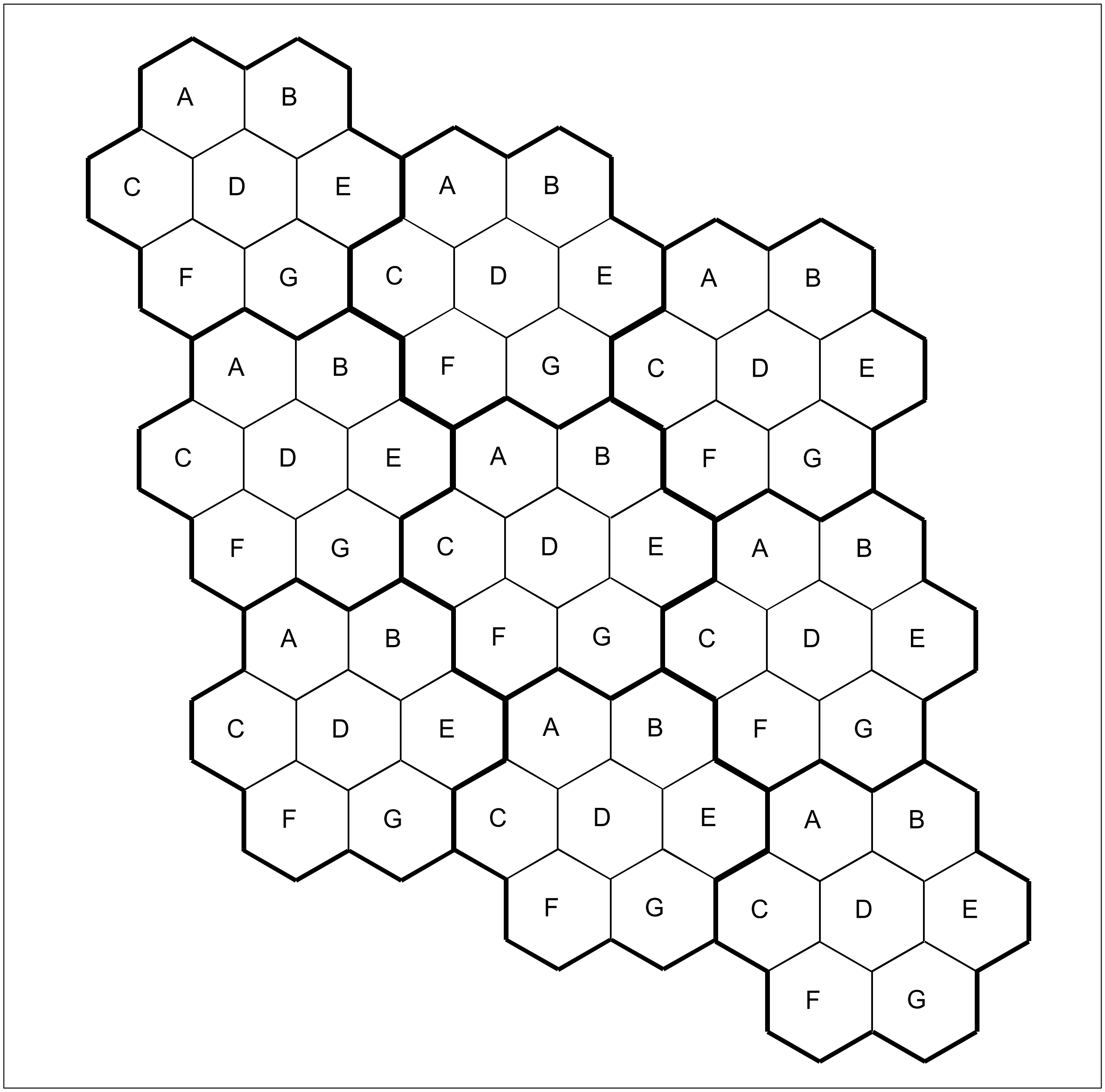


Figure D-4A. Single frequency GRAS VHF networking using multiple time slots

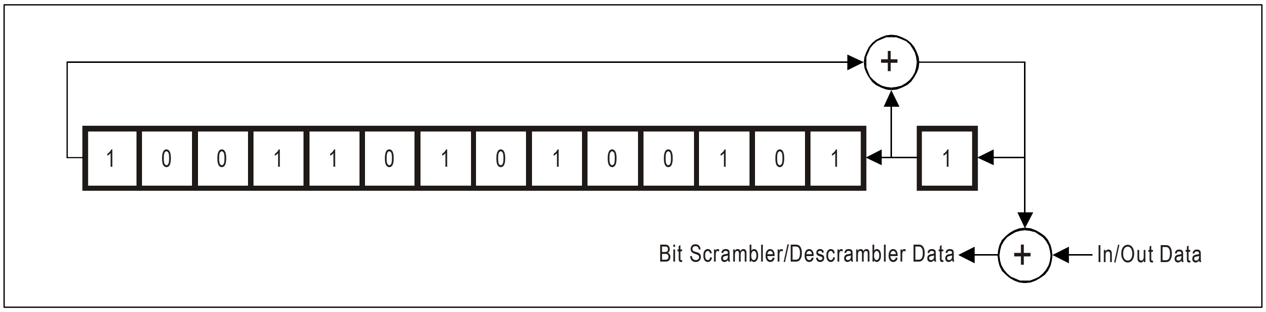
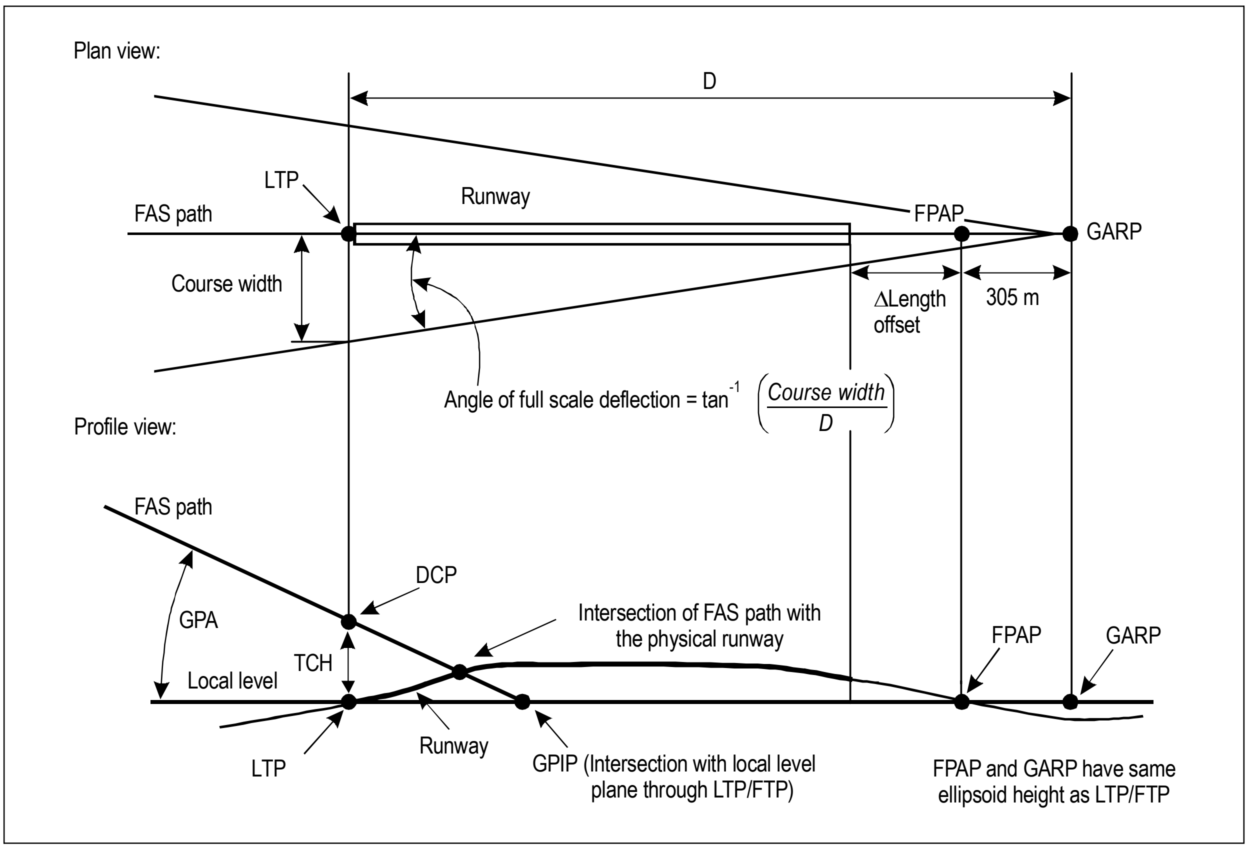
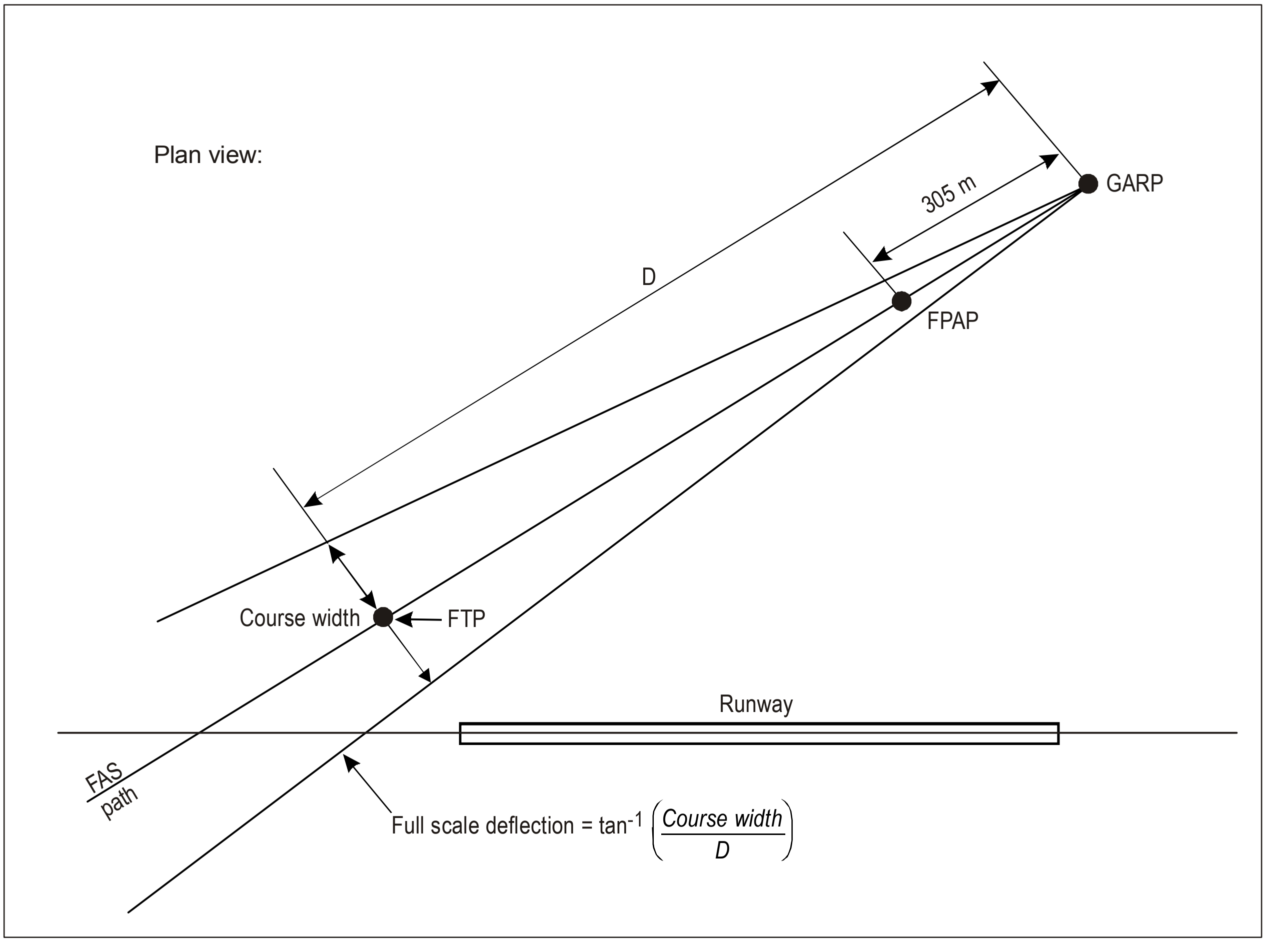


Figure D-5. Bit scrambler/descrambler



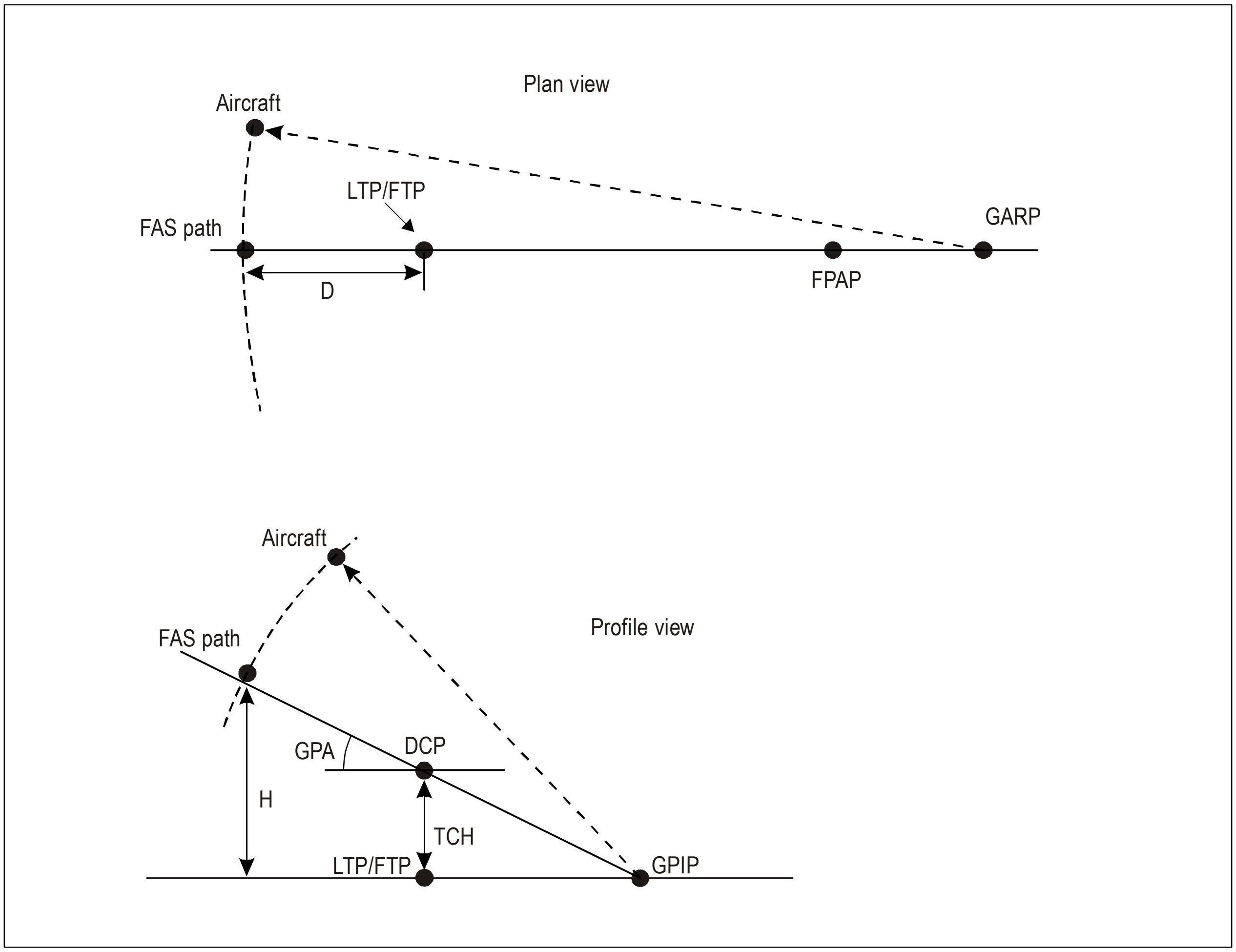
DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — GBAS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-6. FAS path definition



FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point
GARP — GBAS azimuth reference point

Figure D-7. FAS path definition for approaches not aligned with the runway



DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — GBAS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-8. Definition of D and H parameters in alert limit computations

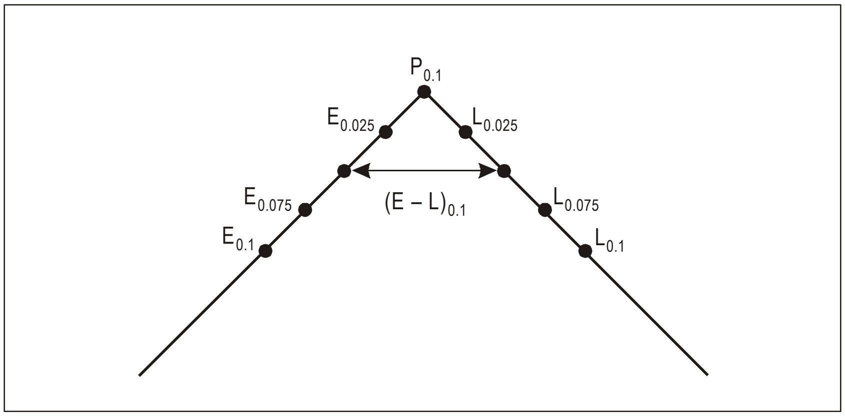


Figure D-9. "Close-in" correlation peak and measured correlator values

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