International Civil Aviation Organization
Eastern and Southern African Office

First Meeting of the APIRG Performance Based Navigation/Global Navigation Satellite System Task Force (PBN/GNSS TF/1)
(Nairobi, Kenya, 12 - 14 October 2010)

Agenda Item 5: AFI GNSS implementation strategy

PROPOSALS FOR THE AMENDMENT OF ANNEX 10, VOLUME I, CONCERNING GBAS

(Presented by the Secretariat)

SUMMARY

This information paper provides the PBN/GNSS Task Force with ICAO State Letter AN 7/1.3.97-10/43 of 22 June 2010 related to proposals for the amendment of Annex 10, Volume I, concerning GBAS, for reference and guidance during its deliberations under Agenda Item 5.

Action by the meeting is at **paragraph 2.**

REFERENCES

-ICAO PBN Manual, Doc 9613

This Working Paper is related to Strategic Objectives: **A** and **D.**

1. INTRODUCTION

1.1 State Letter State Letter AN 7/1.3.97-10/43 of 22 June 2010 is provided in **Appendix** to this paper.

2. CONCLUSION

2.1. The meeting is invited to take note of the information contained in this paper.

— END —

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Ref.: AN 7/1.3.97-10/43 22 June 2010

Subject: Proposals for the amendment of Annex 10, Volume I, concerning the global navigation satellite system (GNSS) ground-based augmentation system (GBAS)

Action required: Comments to reach Montreal by 30 September 2010

Sir/Madam,

1. I have the honour to inform you that the Air Navigation Commission, at the eighth meeting of its 183rd Session held on 9 March 2010, considered proposals developed by the Navigation Systems Panel (NSP) Working Group of the Whole to amend the Standards and Recommended Practices (SARPs) in Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids* concerning the global navigation satellite system (GNSS) ground-based augmentation system (GBAS), as shown in Attachment A, and authorized their transmission to Contracting States and appropriate international organizations for comments.

2. The purpose of the proposed amendment is to reflect the initial experience gained with the ongoing technical implementations of GBAS for Category I operations. A number of changes to the GBAS SARPs are proposed, including the following:

a) removal of material on ground-based ranging functions;

b) clarification of the definition of the GBAS digital modulation method;

c) introduction of an optional authentication protocol;

d) clarification of the B-values coding requirements;

e) introduction of forward compatibility requirements;

f) modification of carrier smoothing requirements for airborne equipment;

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g) modifications to the guidance material on frequency coordination requirements, link budget, vertical deviations, Type 2 message, and signal quality monitoring; and

h) several minor editorial changes.

3. To facilitate your review of the proposed amendments, and pending finalization of an improved State letter format (State letter AN 1/1-10/32 refers), please note that for each amended provision described in Attachment A of the present State letter, a corresponding rationale has been provided in Attachment B. Hyperlinks in the attachments should make it possible to easily navigate between amended provisions and corresponding rationales.

4. In examining the proposed amendments, you should not feel obliged to comment on editorial aspects as such matters will be addressed by the Air Navigation Commission during its final review of the draft amendment.

5. May I request that any comments you may wish to make on the amendment proposals be dispatched to reach me not later than 30 September 2010. The Air Navigation Commission has asked me to specifically indicate that comments received after the due date may not be considered by the Commission and the Council. In this connection, should you anticipate a delay in the receipt of your reply, please let me know in advance of the due date.

6. Furthermore, the Air Navigation Commission requested that States be asked to provide information on their operational experience (if any) with GBAS implementation, including any operational issues or problems identified.

7. For your information, the proposed amendment to Annex 10, Volume I, is envisaged for applicability on 17 November 2011. Any comments you may have thereon would be appreciated.

8. The subsequent work of the Air Navigation Commission and the Council would be greatly facilitated by specific statements on the acceptability or otherwise of the proposals. Please note that, for the review of your comments by the Air Navigation Commission and the Council, replies are normally classified as "agreement with or without comments", "disagreement with or without comments" or "no indication of position". If in your reply the expressions "no objections" or "no comments" are used, they will be taken to mean "agreement without comment" and "no indication of position", respectively. In order to facilitate proper classification of your response, a form has been included in Attachment C which may be completed and returned together with your comments, if any, on the proposals in Attachment A.

Accept, Sir/Madam, the assurances of my highest consideration.

Raymond Benjamin
Secretary General

Enclosures:

A — Proposed amendment to Annex 10, Volume I
B — Rationale for the proposed amendment to Annex 10, Volume I
C — Response form

ATTACHMENT A to State letter AN 7/1.3.97-10/43

PROPOSED AMENDMENT TO ANNEX 10, VOLUME I

NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1.	~~Text to be deleted is shown with a line through it~~.	text to be deleted
2.	New text to be inserted is highlighted with grey shading.	new text to be inserted
3.	~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

PROPOSED AMENDMENT TO

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERONAUTICAL TELECOMMUNICATIONS

ANNEX 10

TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
(RADIO NAVIGATION AIDS)

. . .

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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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.

~~*Note.— Additional GBAS SARPs will be developed to provide ground-based ranging function.*~~

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APPENDIX B. TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

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3.6.2 RF CHARACTERISTICS

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 $\Delta\varphi_k$ represents a counter clockwise rotation in the complex I-Q plane of Figure B-19.

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3.6.4 DATA CONTENT

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

~~*Note.— Currently only 9 of the 256 available message types have been defined, with the intent that future needs can be addressed in the remaining message types.*~~

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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 ~~Reserved for ground-based ranging source~~
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.

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3.6.4.2.4 The measurement block parameters shall be as follows:

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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.

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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
	~~3~~5 to 255	=	spare

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3.6.4.3.2.2 *VDB authentication parameters*

Additional data block 4 includes information needed to support VDB authentication protocols

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-65C. VDB authentication parameters

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

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3.6.4.4 *TYPE 3 MESSAGE—NULL MESSAGE*

~~*Note.— Type 3 message is intended to provide the information required to use ground-based ranging sources and is reserved for future applications.*~~

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.

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3.6.4.5.1 *FAS data block.*

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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 ~~GBAS~~ airport ID, the rightmost (first transmitted) character shall be IA-5 "space".

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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.

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

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3.6.5.1 *Measured and carrier smoothed pseudo-range.*

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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.

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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.

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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	~~±327.67 m/s~~ ±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

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Insert new Table B-71B after Table B-71 and *renumber* Table B-71 as B-71A

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.

End of new text.

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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.

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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; ~~and~~

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.

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~~3.6.7.4 *GROUND-BASED RANGING SOURCES*~~

~~*Note.— Ground-based ranging systems are expected to use a portion of the 1 559 – 1 610 MHz band, which will be classified by the ITU as providing RNSS-ARNS service, and are expected to require up to ±10 MHz around their centre frequency. As augmentations to GPS and/or GLONASS, they will constitute components of GNSS and will have associated avionics receivers. Their interference protection level must be consistent with the interference environment of GNSS receivers.*~~

Insert new text as follows:

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.

End of new text.

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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.

~~*Note.— A GBAS-capable GNSS receiver may be implemented without the capability to process the Type 101 message, the Type 2 message additional data block 2, or data specific to an approach performance designator value of 0.*~~

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3.6.8.3 *AIRCRAFT FUNCTIONAL REQUIREMENTS*

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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".

Insert new text as follows:

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.

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.

END OF NEW TEXT.

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Insert new Table B-82 as follows and *renumber* existing Tables B-82 to B-87 including their corresponding references:

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

END OF NEW TEXT.

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3.6.8.3.5 *Airborne pseudo-range measurements*. ~~Pseudo-range measurement for each satellite shall be smoothed using the carrier measurement and a smoothing filter which deviates less than 0.1 metre within 200 seconds after initialization, relative to the steady-state response of the filter defined in 3.6.5.1 in the presence of drift between the code phase and integrated carrier phase of up to 0.01 metre per second.~~

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:

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

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

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Insert, after Figure B-18, the following new figure:

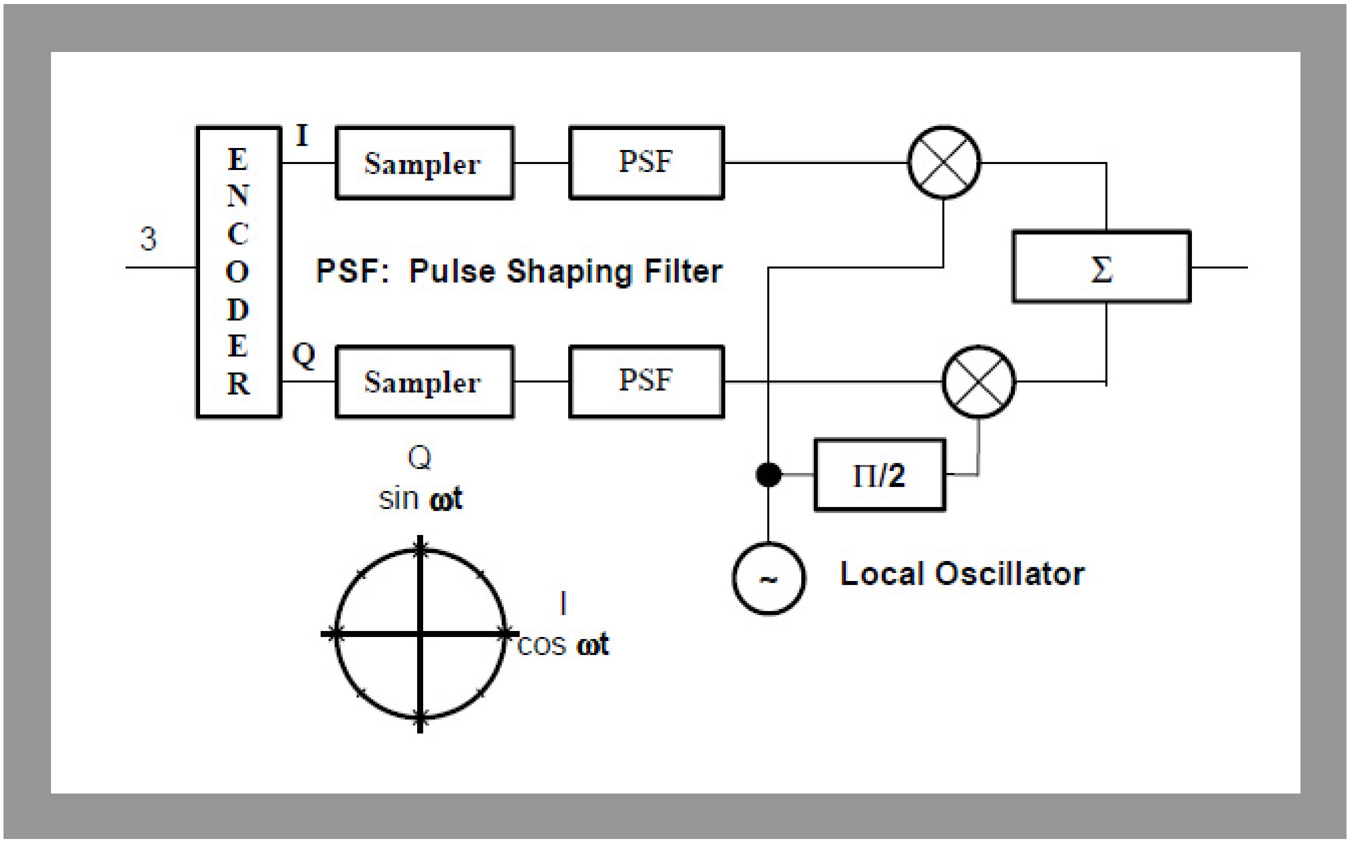

Figure B-19. Example data modulation

End of new text.

ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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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, constitute a loss of continuity event ~~failures~~. In this case, the continuity requirement is stated as a probability for a short exposure time.

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7.1 System description

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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.

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7.2 RF characteristics

7.2.1 *Frequency ~~and time slot planning~~coordination*

7.2.1.1 *Performance factors*

7.2.1.1.1 The geographical separation between a candidate GBAS 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;~~.~~

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 airport. The requirement is found in Appendix B, 3.6.3.4.1.

7.2.1.1.2 ~~The nominal~~ Nominal link ~~budget~~ budgets for VDB ~~is~~ are shown in Table D-3. The ~~figures~~ first example in ~~the table~~ Table D-3 ~~assume~~ 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 allowance 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).

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Table D-3. Nominal VDB link budget

VDB link elements	~~Vertical component link budget at coverage edge~~	~~Horizontal component link budget at coverage edge~~
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

Note 1.— In this table ERP is referenced to an isotropic antenna model.

Note 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 the table above.*

Note 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 is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve -91 dBm to satisfy the nominal link budget.

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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-~~3.3~~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.

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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 ~~requirements~~ 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.

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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.

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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 airport 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}.

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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.

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7.17 Type 2 message additional data blocks ~~block 2~~

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.

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Insert new Table D-8B following Table D-8A:

Table D-8B. Example of 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 – 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 – 101	1	2	0000 0010
Message Length	8	10 – 222 bytes	1 byte	37	0010 0101
Message (Type 2 Example)					
GBAS reference receivers	2	2 - 4	1	3	01
Ground accuracy designator letter	2	-	-	B	01
Spare	1	-	-	-	0
GBAS continuity/integrity designator	3	0 – 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 - 25.5 x10^{-6} m/m	0.1 x10^{-6} m/m	4x10^{-6}	0010 1000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 – 25,500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 – 255	1	20	0001 0100
Latitude	32	± 90.0°	0.0005 arcsec	N45° 40' 32" (+164432")	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	± 180.0°	0.0005 arcsec	W93° 25' 13" (-336313")	1101 0111 1110 1000 1000 1010 1011 0000
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 – 48	1	5	0000 0101
Maximum Use Distance (D_{max})	8	2 – 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 – 12.75	0.05	6	0111 1000
$K_{md\_e\ C,GPS}$	8	0 – 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 – 12.75	0.05	0	0000 0000
$K_{md\_e\ C,GLONASS}$	8	0 – 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 - 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 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.

End of new text.

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8. Signal quality monitor (SQM) design

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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.

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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.

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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).

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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 ~~Table~~ Tables D-13A and D-13B.

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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 ~~range~~ (X) (chips)	Instantaneous correlator spacing ~~range~~ (chips)	Differential group delay
1	(-50 × X) + 12 < BW ~~<~~ ≤7 MHz 2 < BW ≤ 7 MHz	0.1 – 0.2 0.2 – 0.6	0.09 – 0.22 0.18 – 0.65	≤ 600 ns
2	(-50 × X) + 12 < BW ~~<~~ ≤ (40 × X) + 11.2 MHz (-50 × X) + 12 < BW ~~<~~ ≤ 14 MHz 7 < BW ≤ 14 MHz	0.045 – 0.07 0.07 – 0.1 0.1 – 0.24	0.04 – 0.077 0.062 – 0.11 0.09 – 0.26	≤ 150 ns
3	14 < BW ≤ 16 MHz	0.07 – 0.24	0.06 – 0.26	≤ 150 ns

Insert new Table D-13B as follows:

Table D-13B. GPS tracking constraints for GBAS 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 2 < BW ≤ 7 MHz	0.1 – 0.2 0.2 – 0.6	0.09 – 0.22 0.18 – 0.65	≤ 600 ns
2	(-50 × X)+12 < BW ≤ (133.33 × X)+2.667 MHz (-50 × X)+12 < BW ≤ 14 MHz 7 < BW ≤ 14 MHz	0.07 – 0.085 0.085 – 0.1 0.1 – 0.24	0.063 – 0.094 0.077 – 0.11 0.09 – 0.26	≤ 150 ns
3	14 < BW ≤ 16 MHz (133.33 × X)+2.667 < BW ≤ 16 MHz	0.1 – 0.24 0.085 – 0.1	0.09 – 0.26 0.077 – 0.11	≤ 150 ns

End of new text.

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RATIONALE FOR THE PROPOSED AMENDMENT TO ANNEX 10, VOLUME I

Paragraph reference	Rationale
	Chapter 3
3.7.3.5.2	Currently, there are no plans to develop SARPs for ground-based ranging systems (also known as "pseudolites"). Therefore, the existing references to such systems in the Annex are misleading and should be removed.
	Appendix B
3.6.2.2, Figure B-19	The current definition of the GBAS digital modulation scheme is ambiguous. The ambiguity was revealed by interoperability testing between two independent implementations of the Standard which resulted in incompatibility because of different interpretations of the Standard. The proposed change resolves the ambiguity.
3.6.4.1 (Note)	This note addresses the potential introduction of new message types to address future expansion of GBAS functions. It is proposed for deletion because it is no longer necessary, in light of the proposed new Standards in 3.6.8.3.1.2.2, which deal in greater detail with the same topic.
Table B-63	Message type identifier "3" no longer needs to be reserved for ground-based ranging sources (see proposed change to Chapter 3, 3.7.3.5.2). It can therefore be reallocated to a new message type ("Null message"), which supports authentication functions (see proposed change to 3.6.4.3.2).
3.6.4.2.4, 3.6.7.2.2.9	Currently, there is no explicit requirement that each of the parameters B1 through B4 be associated to the same reference receiver over time. Thus, one could interpret the current Standard in 3.6.4.2.4 as permitting to change the association between B-parameter and reference receiver from a transmission frame to the next. This interpretation has been found to create a potential conflict with existing inertial system implementations due to assumptions made in the design of such systems. In order to prevent the conflict an explicit requirement to maintain constant over time the association between B-parameters and reference receivers is proposed to be introduced.
3.6.4.3.2, 3.6.4.3.2.2, 3.6.4.4, 3.6.4.4.1, 3.6.4.4.2, Table B-71B, 3.6.7.2.1.3	These proposed changes define a GBAS authentication protocol intended to prevent potential security threats, specifically "spoofer" threats (whereby wrong data is intentionally provided to the airborne receiver so as to cause the aircraft to follow a wrong path). The authentication protocol is intended to be a mandatory requirement for the future GBAS CAT II/III systems and an optional requirement for GBAS CAT I systems. The protocol is designed in such a way that backward compatibility is guaranteed with respect to the implementation of the protocol. In other words, systems that do not support the protocol can still

Paragraph reference	Rationale
	operate properly together with systems that do support the protocol. In this respect, one minor exception should however be noted. The new Standard in 3.6.7.4.2.1 does impose a new requirement on systems that do not support authentication. This could in principle raise the issue of backward compatibility. However, the impact on existing systems is negligible because actual system design (hardware and software) is not affected. The only aspect of the system that is affected is how a ground station is configured in service to enter the reference path indicator. This is a retroactive configuration requirement on existing stations but given the small number of stations currently in the field it is not deemed to be a problem.
3.6.4.5.1	Editorial changes/clarifications.
3.6.5.1, 3.6.8.3.5, 3.6.8.3.5.1	Implementation experience has shown that the existing requirements on the performance of the smoothing filter for airborne equipment are insufficient to prevent the build-up of differential errors under certain conditions. The proposed change ensures that the carrier smoothing algorithm used by the airborne equipment is defined in such a way as to prevent this potential problem.
Table B-70A	Editorial correction.
3.6.7.4 (including sub-paragraphs)	The rationale for the deletion of the existing text in 3.6.7.4 is the same as the rationale for the change in Chapter 3, 3.7.3.5.2 (there are no plans for introduction of ground-based ranging sources). The rationale for the insertion of the new text in 3.6.7.4 is given above in connection with proposed changes to 3.6.4.3.2 (introduction of GBAS authentication protocol).
3.6.8.1, 3.6.8.3.1.2 (including sub-paragraphs), Table B-82	The new section on airborne processing for forward compatibility explicitly defines the mechanisms by which GBAS SARPs will be expanded to meet future requirements (e.g. CAT II/III operations). Such mechanisms include the definition of new message types, new additional data blocks for Type 2 messages and new data blocks defining reference paths for inclusion within Type 4 messages. The intent of this section is to facilitate the future expansion by ensuring that all current equipment is designed to ignore data formats that are not recognized (as opposed to malfunctioning or reacting in an unpredictable way).
Attachment D	
3.4.3.1, 7.1.5, 7.1.6	Editorial.
7.2.1, 7.2.1.1.1	The existing guidance on coordination requirements for GBAS installations does not mention the fact that, in addition to frequency and time slot planning, reference path data selectors (RPDS), reference station data selectors (RSDS) and reference path indicators (RPI) need to be coordinated between ground facilities. The proposed change highlights the need for such coordination.
7.2.1.1.2, Table D-3	The existing nominal GBAS link budget is geared to supporting GBAS approach service but imposes unpractical requirements on the ground transmitter power

Paragraph reference	Rationale
	required to achieve a viable service volume for the GBAS positioning service. The proposed changes introduce an alternative link budget for the positioning service, taking into account applicable mitigations (e.g. more favourable fade margin requirements than in the approach service case).
7.6.2	The proposed change is a consequence of the corresponding change to Table 3.7.2.4-1 introduced by Amendment 83.
7.11.3 (including sub-paragraphs)	Clarification explaining why, for GBAS, the angle at which full scale deviation is attained was chosen to be equal to 0.25 * GPA instead of 0.24 * GPA as recommended for ILS.
7.11.6, 7.15.4.1, 7.17.5, Table D8-B	Introduction of GBAS authentication protocol (see detailed rationale provided in connection with proposed changes to Appendix B, 3.6.4.3.2).
7.17 (including sub-paragraphs 7.17.1 to 7.17.4)	Definition of the mechanisms by which GBAS SARPs will be expanded to meet future requirements (see detailed rationale provided in connection with proposed changes to Appendix B, 3.6.8.3).
8 (including sub-paragraphs), Tables D-13A and D-13B	The proposed changes are the result of experience gained during the CAT I ground station implementation. The tracking constraints defined in the new table for the GBAS airborne receiver are more stringent than those in the existing table in order to limit the complexity of the GBAS ground monitor. No practical impact on airborne receiver design is expected.

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ATTACHMENT C to State letter AN 7/1.3.97-10/43

RESPONSE FORM TO BE COMPLETED AND RETURNED TO ICAO TOGETHER WITH ANY COMMENTS YOU MAY HAVE ON THE PROPOSED AMENDMENTS

To: The Secretary General
International Civil Aviation Organization
999 University Street
Montreal, Quebec
Canada, H3C 5H7

(**State)** ________________________________

Please make a checkmark (✓) against one option for each amendment. If you choose options "agreement with comments" or "disagreement with comments", **please provide your comments on separate sheets.**

	Agreement without comments	*Agreement with comments**	*Disagreement without comments*	*Disagreement with comments*	*No position*
Amendment Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids* (Attachment A refers)					

* "Agreement with comments" indicates that your State or organization agrees with the intent and overall thrust of the amendment proposal; the comments themselves may include, as necessary, your reservations concerning certain parts of the proposal and/or offer an alternative proposal in this regard.

Signature ________________________________ Date ________________________________

— END —