MEMORANDUM CIRCULAR NO.: 06-18

TO : ALL CONCERNED

FROM : DIRECTOR GENERAL

SUBJECT : AMENDMENT TO PHILIPPINE CIVIL AVIATION REGULATIONS - AIR NAVIGATION SERVICES (CAR-ANS) PART 6 INCORPORATING AMENDMENT 90 TO ICAO ANNEX 10 VOLUME 1

REFERENCE:

1. Philippine Civil Aviation Regulations- Air Navigation Services Part 6, Issue 3 Amendment No. 6
2. ICAO Annex 10 Volume 1; Amendment 89
3. CAAP Regulations Amendment Procedures
4. Board Resolution No. 2012-054 dated 28 September 2012

Pursuant to the powers vested in me under the Republic Act 9497, otherwise known as the Civil Aviation Authority Act of 2008 and in accordance with the Board Resolution No.: 2012-054 dated 28 September 2012, I hereby approve the incorporation of ICAO Annex 10 Volume 1 Amendment No. 90 to the Philippine Civil Aviation Regulations – Air Navigation Services (CAR-ANS) Part 6.

ORIGINAL REGULATION SUBJECT FOR REVIEW AND REVISION:

CAR-ANS Part 6

…

6. 2 GENERAL PROVISIONS FOR RADIO NAVIGATION AIDS

6.2.1 Standard radio navigation aids

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Note 2.— It is intended that introduction and application of radio navigation aids to support precision approach and landing operations will be in accordance with the strategy shown in Attachment 6B. It is intended that rationalization of conventional radio navigation aids and evolution toward supporting performance-based navigation will be in accordance with the strategy shown in Attachment 6H.

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6.3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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6.3.1 Specification for ILS

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6.3.1.2 Basic requirements

6.3.1.2.1 The ILS shall comprise the following basic components:

a) VHF localizer equipment, associated monitor system, remote control and indicator equipment;

b) UHF glide path equipment, associated monitor system, remote control and indicator equipment;

c) ~~VHF marker beacons, or distance measuring equipment (DME) in accordance with section 6.3.5, together with associated monitor system and remote control and indicator equipment.~~an appropriate means to enable glide path verification checks.

Note.— The Procedures for Air Navigation Services — Aircraft Operations *(PANS-OPS) (Doc 8168) provide guidance on the conduct of glide path verification checks.*

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6.3.1.2.1.1 Distance to threshold information to enable glide path verification checks should be provided by either VHF marker beacons or distance measuring equipment (DME), together with associated monitor systems and remote control and indicator equipment.

6.3.1.2.1.2 If one or more VHF marker beacons are used to provide distance to threshold information, the equipment shall conform to the specifications in 6.3.1.7. If DME is used in lieu of marker beacons, the equipment shall conform to the specifications in 6.3.1.7.6.5.

Note.— Guidance material relative to the use of DME and/or other standard radio navigation aids as an alternative to the marker ~~beacon component of the ILS~~ is contained in Attachment 6C, 6.2.11.

6.3.1.2.1.~~1~~3 Facility Performance Categories I, II and III — ILS shall provide indications at designated remote control points of the operational status of all ILS ground system components, as follows:

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6.3.1.7 VHF marker beacons

Note.— Requirements relating to marker beacons apply only when one or more marker beacons are Installed.

6.3.1.7.1 *General*

a) There shall be two marker beacons in each installation except ~~as provided in 6.3.1.7.6.5~~ where, in the opinion of the Competent Authority, a single marker beacon is considered to be sufficient. A third marker beacon may be added whenever, in the opinion of the Competent Authority, an additional beacon is required because of operational procedures at a particular site.

b) ~~The~~ A marker beacons shall conform to the requirements prescribed in 6.3.1.7. When the installation comprises only two marker beacons, the requirements applicable to the middle marker and to the outer marker shall be complied with. When the installation comprises only one marker beacon, the requirements applicable to either the middle or the outer marker shall be complied with. If marker beacons are replaced by DME, the requirements of 6.3.1.7.6.5 shall apply.

c) The marker beacons shall produce radiation patterns to indicate predetermined distance from the threshold along the ILS glide path.

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6.3.1.7.3 *Coverage*

6.3.1.7.3.1 The marker beacon system shall be adjusted to provide coverage over the following distances, measured on the ILS glide path and localizer course line:

a) *inner marker ~~(where installed)~~:* 150 m plus or minus 50 m (500 ft plus or minus 160 ft);

b) *middle marker:* 300 m plus or minus 100 m (1 000 ft plus or minus 325 ft);

c) *outer marker:* 600 m plus or minus 200 m (2 000 ft plus or minus 650 ft).

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6.3.1.7.4 *Modulation*

6.3.1.7.4.1 The modulation frequencies shall be as follows:

a) *inner marker ~~(when installed)~~:* 3 000 Hz;

b) *middle marker:* 1 300 Hz;

c) *outer marker:* 400 Hz.

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6.3.1.7.5 *Identification*

6.3.1.7.5.1 The carrier energy shall not be interrupted. The audio frequency modulation shall be keyed as follows:

a) *inner marker ~~(when installed):~~* 6 dots per second continuously;

b) *middle marker:* a continuous series of alternate dots and dashes, the dashes keyed at the rate of 2 dashes per second, and the dots at the rate of 6 dots per second;

c) *outer marker:* 2 dashes per second continuously.

These keying rates shall be maintained to within plus or minus 15 per cent.

6.3.1.7.6 *Siting*

6.3.1.7.6.1 The inner marker~~, when installed,~~ shall be located so as to indicate in low visibility conditions the imminence of arrival at the runway threshold.

6.3.1.7.6.1.1 If the radiation pattern is vertical, the inner marker, ~~when installed,~~ should be located between 75 m (250 ft) and 450 m (1 500 ft) from the threshold and at not more than 30 m (100 ft) from the extended centre line of the runway.

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6.3.7 Requirements for the Global Navigation Satellite System (GNSS)

6.3.7.1 Definitions

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Antenna port. A point where the received signal power is specified. For an active antenna, the antenna port is a fictitious point between the antenna elements and the antenna pre-amplifier. For a passive antenna, the antenna port is the output of the antenna itself.

Axial ratio. The ratio, expressed in decibels, between the maximum output power and the minimum output power of an antenna to an incident linearly polarized wave as the polarization orientation is varied over all directions perpendicular to the direction of propagation.

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6.3.7.3 GNSS elements specifications

6.3.7.3.1 *GPS Standard Positioning Service (SPS) (L1)*

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6.3.7.3.1.7.4 *Signal power level*. Each GPS satellite shall broadcast SPS navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the ~~output~~ antenna port of a 3 dBi linearly-polarized antenna is within the range of –158.5 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

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6.3.7.3.2 *GLONASS Channel of Standard Accuracy (CSA) (L1)*

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6.3.7.3.2.5.4 *Signal power level*. Each GLONASS satellite shall broadcast CSA navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the ~~output~~ antenna port of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

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Note 2.— GLONASS-M satellites will also broadcast a ranging code on L2 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the ~~output~~ antenna port of a 3 dBi linearly polarized antenna is not less then –167 dBW for all antenna orientations orthogonal to the direction of propagation.

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6.3.7.3.4 *Satellite-based augmentation system (SBAS)*

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6.3.7.3.4.4.3 *~~Signal~~ SBAS satellite-signal power level*

6.3.7.3.4.4.3.1 Each SBAS satellite placed in orbit before 1 January 2014 shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the ~~output~~ antenna port of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

6.3.7.3.4.4.3.2 Each SBAS satellite placed in orbit after 31 December 2013 shall comply with the following requirements:

a) The satellite shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at or above the minimum elevation angle for which a trackable GEO signal needs to be provided, the level of the received RF signal at the ~~output~~ antenna port of the antenna specified in Appendix B, Table ~~B-87~~B-88, is at least –164.0 dBW.

~~6.3.7.3.4.4.3.2.1 *Minimum elevation angle.*~~b) The minimum elevation angle used to determine GEO coverage shall not be less than 5 degrees for a user near the ground.

~~6.3.7.3.4.4.3.2.2~~c) The level of a received SBAS RF signal at the ~~output~~ antenna port of a 0 dBic antenna located near the ground shall not exceed –152.5 dBW.

d) The ellipticity of the broadcast signal shall be no worse than 2 dB for the angular range of ±9.1° from boresight.

6.3.7.3.4.4.4 *Polarization.* The broadcast signal shall be right-hand circularly polarized.

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APPENDIX 6B. TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

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~~3.2.5.2 *Conversion between PZ-90 and WGS-84. The following conversion parameters shall be used to obtain position coordinates in WGS-84 from position coordinates in PZ-90 (Version 2):*~~

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} = \begin{bmatrix} -0.36 \\ +0.08 \\ +0.18 \end{bmatrix} + \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{PZ-90}$$

~~*Note .— X, Y and Z are expressed in metres.*~~

~~3.2.5.2.1 The conversion error shall not exceed 0.1 metres (1 sigma) along each coordinate axis.~~

3.2.5.2 *CONVERSION BETWEEN PZ-90 AND WGS-84*

3.2.5.2.1 The following conversion parameters should be used to obtain position coordinates in WGS-84 (version G1674) from position coordinates in PZ-90 (Version PZ-90.11):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} = \begin{bmatrix} 1 & 0.0097 \times 10^{-9} & 0.2036 \times 10^{-9} \\ -0.0097 \times 10^{-9} & 1 & 0.0921 \times 10^{-9} \\ -0.2036 \times 10^{-9} & 0.0921 \times 10^{-9} & 1 \end{bmatrix} \times \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{PZ-90} + \begin{bmatrix} 0.003 \\ 0.001 \\ 0 \end{bmatrix}$$

Note 1.— X, Y and Z are expressed in metres. The difference between versions WGS-84 (G1674) and PZ-90 (PZ-90.11) is not significant with respect to operational requirements.

Note 2.— Guidance material on conversion between PZ-90 and WGS-84 is provided in Attachment 6D, section 4.2.9.3.

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3.3.1.3 *Conversion between coordinate systems*. Position information provided by a combined GPS and GLONASS receiver shall be expressed in WGS-84 earth coordinates. ~~The GLONASS satellite position, obtained in PZ-90 coordinate frame, shall be converted to account for the differences between WGS-84 and PZ-90, as defined in 3.2.5.2.~~

3.3.1.3.1 The GLONASS satellite position, obtained in PZ-90 coordinate frame, should be converted to account for the differences between WGS-84 and PZ-90, as defined in 3.2.5.2.

3.3.1.4 *GPS/GLONASS time*. When combining measurements from GLONASS and GPS, the difference between GLONASS time and GPS time shall be taken into account.

3.3.1.4.1 GPS/GLONASS receivers shall solve for the time offset between the core constellations as an additional unknown parameter in the navigation solution and not only rely on the time offset broadcast in the navigation messages.

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3.5 Satellite-based augmentation system (SBAS)

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3.5.4.2 *Geostationary orbit (GEO) ranging function parameters.* GEO ranging function parameters shall be as follows:

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User range accuracy (URA): an indicator of the root-mean-square ranging error, excluding atmospheric effects, as described in Table B-26.

Note.— All parameters are broadcast in Type 9 message.

Table B-26. User range accuracy

URA	Accuracy (rms)
0	2 m
1	2.8 m
2	4 m
3	5.7 m
4	8 m
5	11.3 m
6	16 m
7	32 m
8	64 m
9	128 m
10	256 m
11	512 m
12	1 024 m
13	2 048 m
14	4 096 m
15	"Do Not Use"

Note.— URA values 0 to 14 are not used in the protocols for data application (3.5.5). Airborne receivers will not use the GEO ranging function if URA indicates "Do Not Use"(3.5.8.3).

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3.5.5.4 *Range rate corrections (RRC)*. The range rate correction for satellite *i* is:

~~$$\mathrm{RRC}_i = \frac{\mathrm{FC}_{i,current} - \mathrm{FC}_{i,previous}}{t_{i,0f} - t_{i,0f\_previous}}$$~~

$$\mathrm{RRC}_i = \begin{cases} \dfrac{\mathrm{FC}_{i,\mathrm{current}} - \mathrm{FC}_{i,\mathrm{previous}}}{t_{i,0f} - t_{i,0f\_\mathrm{previous}}}, & if\ a_i \neq 0 \\ 0, & if\ a_i = 0 \end{cases}$$

where
$FC_{i,\,current}$ = the most recent fast correction;
$FC_{i,previous}$ = a previous fast correction;
$t_{i,0f}$ = the time of applicability of $FC_{i,current}$; ~~and~~
$t_{i,0f\ previous}$ = the time of applicability of $FC_{i,previous}$~~.~~; and
a_i = fast correction degradation factor (see Table B-34).
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3.5.5.6.3.1 *Broadcast ionospheric corrections.* If SBAS-based ionospheric corrections are applied, σ^2_{UIRE} is:

$$\sigma^2_{UIRE} = F^2_{pp} \times \sigma^2_{UIVE}$$

where

F_{pp} = (as defined in 3.5.5.5.2);

$$\sigma^2_{UIVE} = \sum_{n=1}^{4} W_n \cdot \sigma^2_{n,ionogrid} \text{ or } \sigma^2_{UIVE} = \sum_{n=1}^{3} W_n \cdot \sigma^2_{n,ionogrid}$$

using the same ionospheric pierce point weights (Wn) and grid points selected for the ionospheric correction (3.5.5.5).
~~For~~

If degradation parameters are used, for each grid point:

$$\sigma^2_{n,ionogrid} = \begin{cases} \left(\sigma_{n,GIVE} + \varepsilon_{iono}\right)^2, & \text{if } RSS_{iono} = 0 \text{ (Type 10 message)} \\ \sigma^2_{n,GIVE} + \varepsilon^2_{iono}, & \text{if } RSS_{iono} = 1 \text{ (Type 10 message)} \end{cases}$$

where

$$\varepsilon_{iono} = C_{iono\_step}\left[\frac{t - t_{iono}}{I_{iono}}\right] + C_{iono\_ramp}(t - t_{iono});$$

t = the current time;
t_{iono} = the time of transmission of the first bit of the ionospheric correction message at the GEO; and
$[x]$ = the greatest integer less than x.

If degradation parameters are not used, for each grid point:

$$\sigma_{n,ionogrid} = \sigma_{n,GIVE}$$

Note.— For GLONASS satellites, both σ_{GIVE} and ~~σ_{IONO}~~ -ε_{iono} parameters are to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies (fGLONASS/fGPS)[2].
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~~3.5.5.6.3.3 *GLONASS clock.* The degradation parameter for GLONASS clock correction is:~~
~~$\varepsilon_{GLONASS\_CLOCK} = C_{GLONASS\_CLOCK} \bullet [t - t_{GLONASS\_CLOCK}]$~~

~~where~~
~~t = the current time~~
~~$t_{GLONASS\_CLOCK}$ = the time of transmission of the first bit of the timing message (MT12) at the GEO[sc] = the greatest integer less than sc.~~

~~*Note 1.— For non-GLONASS satellites $\varepsilon_{GLONASS\_CLOCK}$ = 0.*~~

~~*Note 2.— $C_{GLONASS\_CLOCK}$ = 0.00833 cm/s.*~~

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3.5.7.1.2 *SBAS radio frequency monitoring.* The SBAS shall monitor the SBAS satellite parameters shown in Table B-55 and take the indicated action.

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Table B-55. SBAS radio frequency monitoring

Parameter	Reference	Alarm limit	Required action
Signal power level	Chapter 3, 3.7.3.4.4.3	minimum specified power ~~= 161 dBW~~ maximum specified power ~~= 153 dBW~~ (Note 2)	~~Minimum:~~ ~~c~~Cease ranging function (Note 1). ~~Maximum:~~ ~~c~~Cease broadcast.
Modulation	Chapter 3, 3.7.3.4.4.5	monitor for waveform distortion	Cease ranging function (Note 1).
SNT-to-GPS time	Chapter 3, 3.7.3.4.5	N/A (Note 3)	Cease ranging function unless σ_{UDRE} ~~URA~~ reflects error.
Carrier frequency stability	3.5.2.1	N/A (Note 3)	Cease ranging function unless σ^2_{UDRE} ~~and URA~~ reflects error.
Code/frequency coherence	3.5.2.4	N/A (Note 3)	Cease ranging function unless σ^2_{UDRE} ~~and URA~~ reflects error.
Maximum code phase deviation	3.5.2.6	N/A (Notes 2 and 3)	Cease ranging function unless σ^2_{UDRE} ~~and URA~~ reflects error.
Convolutional encoding	3.5.2.9	all transmit messages are erroneous	Cease broadcast.

Notes.—

1. *Ceasing the ranging function is accomplished by broadcasting a URA and σ^2_{UDRE} of "Do Not Use" for that SBAS satellite.*
2. *These parameters can be monitored by their impact on the received signal quality (C/N_0 impact), since that is the impact on the user.*
3. *Alarm limits are not specified because the induced error is acceptable, provided it is represented in the σ^2_{UDRE} and URA parameters. If the error cannot be represented, the ranging function must cease.*

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3.5.7.3.2 *PRN mask and Issue of data — PRN (IODP)*. SBAS shall broadcast a PRN mask and IODP (Type 1 message). The PRN mask values shall indicate whether or not data are being provided for each GNSS satellite. The IODP shall change when there is a change in the PRN mask. The change of IODP in Type 1 messages shall occur before the IODP changes in any other message. The IODP in Type 2 to 5, 7, 24 ~~and~~, 25 and 28 messages shall equal the IODP broadcast in the PRN mask message (Type 1 message) used to designate the satellites for which data are provided in that message.

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3.5.7.5.1 *Performance of precise differential correction function.* Given any valid combination of active data, the probability of an out-of-tolerance condition for longer than the relevant time-to-alert shall be less than 2 × 10–7 during any approach, assuming a user with zero latency. The time-to-alert shall be 5.2 seconds for an SBAS that supports precision approach ~~or APV-II~~ operations, and 8 seconds for an SBAS that supports APV~~-I~~ or NPA operations. An out-of-tolerance condition shall be defined as a horizontal error exceeding the HPLSBAS or a vertical error exceeding the VPLSBAS (as defined in 3.5.5.6). When an out-of tolerance condition is detected, the resulting alert message (broadcast in a Type 2 to 5 and

6, 24, 26 or 27 messages) shall be repeated three times after the initial notification of the alert condition for a total of four times in 4 seconds.

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3.5.7.7.2.5 SBAS shall raise an alarm within 5.2 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for precision approach ~~or APV II~~ (3.5.7.5.1).

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3.5.7.7.2.6 SBAS shall raise an alarm within 8 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for en-route through APV I (3.5.7.4.1).

Note.— The monitoring applies to all failure conditions, including failures in core satellite constellation(s) or SBAS satellites. This monitoring assumes that the aircraft element complies with the requirements of RTCA/DO-229~~CD~~ with Change 1, except as superseded by 3.5.8 and Attachment 6D, 8.11.

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3.5.8.1 *SBAS-capable GNSS receiver*. Except as specifically noted, the SBAS-capable GNSS receiver shall process the signals of the SBAS and meet the requirements specified in 3.1.3.1 (GPS receiver) and/or 3.2.3.1 (GLONASS receiver). Pseudo-range measurements for each satellite shall be smoothed using carrier measurements and a smoothing filter which deviates less than ~~0.1~~ 0.25 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~~0.018 metre per second.

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3.5.8.1.2 *Conditions for use of data*. The receiver shall use data from an SBAS message only if the CRC of this message has been verified. Reception of a Type 0 message from an SBAS satellite shall result in deselection of that satellite for at least one minute and all data from that satellite shall be discarded ~~for at least 1 minute~~, except that there is no requirement to discard data from Type 12 and Type 17 messages. For GPS satellites, the receiver shall apply long-term corrections only if the IOD matches both the IODE and 8 least significant bits of the IODC.[…]

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3.5.8.1.2.6 The receiver shall apply satellite-specific degradation to the $\sigma_{i,UDRE}^2$ as defined by a Type 28 clock-ephemeris covariance matrix message. The δ_{UDRE} derived from a Type 28 message with an IODP matching that of the PRN mask shall be applied immediately.

3.5.8.1.2.7 In the event of a loss of four successive SBAS messages during an SBAS-based approach operation with a HAL of 40 m or a VAL of 50 m or less, the receiver shall ~~no longer support SBAS-based precision approach or APV operations~~ invalidate all UDREI data from that SBAS satellite.

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3.5.8.4.1 *Core satellite constellation(s) ranging accuracy.* The root-mean-square (1 sigma) of the total airborne contribution to the error in a corrected pseudo-range for a GPS satellite at the minimum and maximum received signal power level (Chapter 6.3, 6.3.7.3.1.5.4) under the worst interference environment as defined in 6.3.7 shall be less than or equal to ~~0.4~~ 0.36 metres for minimum signal level and 0.15 metres for maximum signal level, excluding multipath effects, tropospheric and ionospheric residual errors. […]

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3.5.8.4.2 *Precision approach and APV operations*

3.5.8.4.2.1 The receiver shall obtain correction and integrity data for all satellites in the position solution from the same SBAS signal (PRN code).

3.5.8.4.2.~~1~~2 The receiver shall compute and apply long-term corrections, fast corrections, range rate corrections and the broadcast ionospheric corrections. For GLONASS satellites, the ionospheric corrections received from the SBAS shall be multiplied by the square of the ratio of GLONASS to GPS frequencies $(f_{GLONASS}/f_{GPS})^2$.

3.5.8.4.2.~~2~~3 The receiver shall use a weighted-least-squares position solution.

3.5.8.4.2.~~3~~4 The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a 1 sigma deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment 6D, ~~6.7.3~~ 6.5.4.

3.5.8.4.2.~~4~~5 The receiver shall compute and apply horizontal and vertical protection levels defined in 3.5.5.6. In this computation, ~~σ_{tropo}~~$\sigma_{i,tropo}$ shall be:

~~1 / √(0,002 + sen²(θi)) × 0,12 m~~

$$\frac{1.001}{\sqrt{0.002001 + \sin^2(\theta_i)}} \times 0.12\ \text{m}$$

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

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

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

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

$f_{ni}(x)$ = 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.

3.5.8.4.2.~~5~~6 The parameters that define the approach path for a single precision approach or APV shall be contained in the FAS data block.

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3.5.8.4.2.~~5.1~~6.1 FAS data block parameters shall be as follows (see Table B-57A):

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3.5.8.4.2.~~5.2~~6.2 For precision approach and APV operations, the service provider ID broadcast Type 17 message shall be identical to the service provider ID in the FAS data block, except if ID equals 15 in the FAS data block.

Note.— If the service provider ID in the FAS data block equals 15, then any service provider can be used. If the service provider ID in the FAS data block equals 14, then SBAS precise differential corrections cannot be used for the approach.

3.5.8.4.2.~~5.3~~6.3 *SBAS FAS data points accuracy.* 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

3.5.8.4.3 *Departure, en-route, terminal, and non-precision approach operations*

3.5.8.4.3.1 The receiver shall compute and apply long-term corrections, fast corrections and range rate corrections.

3.5.8.4.3.2 The receiver shall compute and apply ionospheric corrections.

Note.— Two methods of computing ionospheric corrections are provided in 3.1.2.4 and 3.5.5.5.2.

3.5.8.4.3.3 The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a standard deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment D, ~~6.7.3~~6.5.4.

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}~~σ_{tropo} shall be~~:~~ obtained either from the formula in 3.5.8.4.2.5, which can be used for elevation angles not less than 4 degrees, or from the alternate formula below, which can be used for elevation angles not less than 2 degrees.

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

$$\frac{1.001}{\sqrt{0.002001 + \sin^2(\theta_i)}} \times \left(1 + 0.015 \times \left(\max(0, 4 - \theta_i)\right)^2\right) \times 0.12\ \text{m}$$

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

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

$$\int_{y}^{\infty} f_{ni}(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_{ni}(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

$f_{ni}(x)$ = 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.

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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~~0.36 m*	*0.8 m*

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Note 6.— The performance requirements are to be met in the interference environments defined below ~~for various phases of flight~~. This defined interference environment is relaxed during initial acquisition of GNSS signals when the receiver cannot take advantage of a steady-state navigation solution to aid signal acquisition.

3.7.2 CONTINUOUS WAVE (CW) INTERFERENCE

3.7.2.1 *GPS AND SBAS RECEIVERS*

3.7.2.1.1 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 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~~ 164 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~~During initial acquisition of ~~the~~ GPS and SBAS signals prior to steady-state navigation, the GPS and SBAS receivers shall meet the performance objectives with 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 in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers ~~used for precision approach phase of flight~~ in steady-state navigation
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ ~~1 525~~1 500 MHz	Linearly decreasing from –4.5 dBW to ~~–42~~ –38 dBW
1 500 MHz < $f_i \leq$ 1 525 MHz	Linearly decreasing from –38 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 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~~(except those identified in 3.7.2.2.1.1) 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~~ –166.5 dBW at the antenna port.

3.7.2.2.1.1 After steady-state navigation has been established, GLONASS receivers used for all phases of flight (excluding those used for the precision approach phase of flight) and put into operation before 1 January 2017 shall meet the performance objectives with CW interfering signals present with a power level at the antenna port 3 dB less than the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level of – 166.5 dBW at the antenna port.

Table B-84. CW ~~I~~interference thresholds for GLONASS receivers in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers ~~used for precision approach phase of flight~~in steady-state navigation
$f_i \leq$ 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~~ During initial acquisition of the

GLONASS signals prior to steady-state navigation, ~~the~~ GLONASS receivers shall meet the performance objectives with 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 ±Bw_i/2 and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and shown in Figure B-17 and with the desired signal level of ~~–164.5~~ –164 dBW at the antenna port.

Note.— Bwi 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~~ During initial acquisition of the GPS and SBAS signals prior to steady-state navigation, ~~the~~ GPS and SBAS receivers shall meet the performance objectives with interference thresholds ~~for bandlimited 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~~(except those identified in 3.7.3.2.1.1) shall meet the performance objectives while receiving noise-like interfering signals in the frequency band fk ±Bwi/2, with power levels at the antenna port equal to the interference thresholds ~~defined~~ specified in Table B-86 and shown in Figure B-18 and with a desired signal level of ~~–165.5~~ –166.5 dBW at the antenna port.

3.7.3.2.1.1 After steady-state navigation has been established, GLONASS receivers used for all phases of flight (excluding those used for the precision approach phase of flight) and put into operation before 1 January 2017 shall meet the performance objectives while receiving noise-like interfering signals in the frequency band fk ±Bwi/2, with power levels at the antenna port 3 dB less than the interference thresholds specified in Table B-86 and shown in Figure B-18 and with a desired signal level of –166.5 dBW at the antenna port.

Note.— fk is the centre frequency of a GLONASS channel with fk = 1 602 MHz + k × ~~0.6525~~ 0.5625 MHz and k = -7 to +~~13~~6 as defined in Table B-16 and Bwi 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~~ During initial acquisition of ~~the~~ GLONASS signals prior to steady-state navigation, the GLONASS receivers shall meet the performance objectives with 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.*~~

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

3.8.3.1 The antenna axial ratio shall not exceed 3.0 dB as measured at boresight.

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

Interference bandwidth	Interference threshold for receivers in steady-state navigation
0 Hz < Bw_i ≤ 700 Hz	−150.5 dBW
700 Hz < Bw_i ≤ 10 kHz	Linearly increasing from −150.5 to −143.5 dBW ~~−150.5 + 6 log₁₀(BW/700) dBW~~
10 kHz < Bw_i ≤ 100 kHz	Linearly increasing from −143.5 to −140.5 dBW ~~−143.5 + 3 log₁₀(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 in steady-state navigation

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 for in-band and near-band	1 575.42 MHz ± ~~10~~ 20 MHz	1 592.9525 MHz to 1 609.36 MHz
Interference threshold (Pulse peak power) for in-band and near-band interference	−20 dBW	−20 dBW
Interference threshold (Pulse peak power) outside the in-band and near-band frequency ranges (out-of-band interference)	0 dBW	0 dBW
Pulse width	≤125 µs	≤250 µs
Pulse duty cycle	≤1%	≤1%
Interference signal bandwidth for in-band and near-band interference	≥1 MHz	≥500 kHz

Note 1.— The interference signal is additive white Gaussian noise centred around the carrier frequency and with bandwidth and pulse characteristics specified in the table.
Note 2.— In-band, near-band and out-of-band interference refers to the centre frequency of the interference signal.

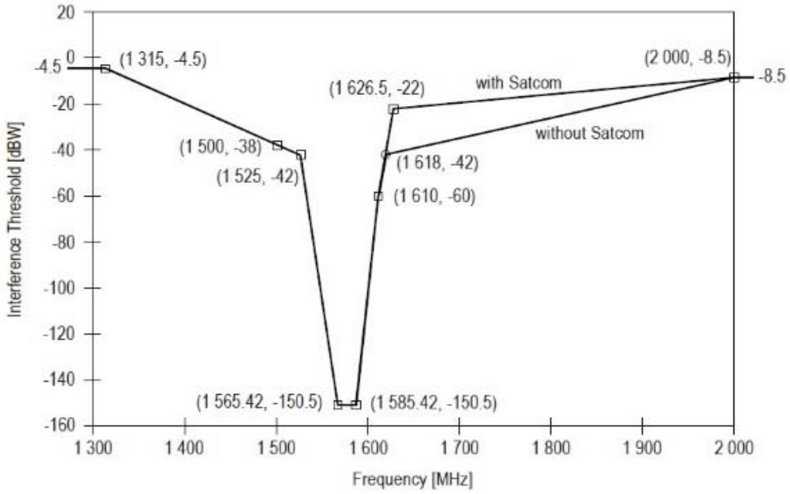

Figure B-15. CW interference thresholds for GPS and SBAS receivers ~~used for precision approach~~ in steady-state navigation

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(Replace Figure B-17 with the figure below.)

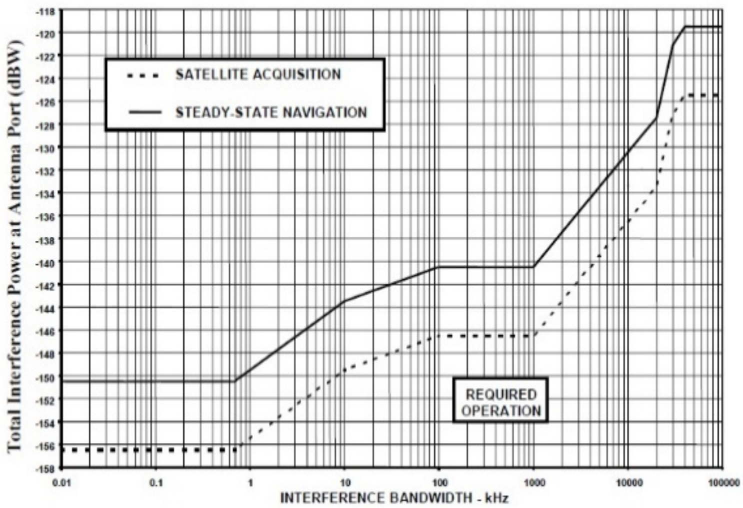

Figure B-17. Interference thresholds versus bandwidth for GPS and SBAS receivers

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(Replace Figure B-18 with the figure below.)

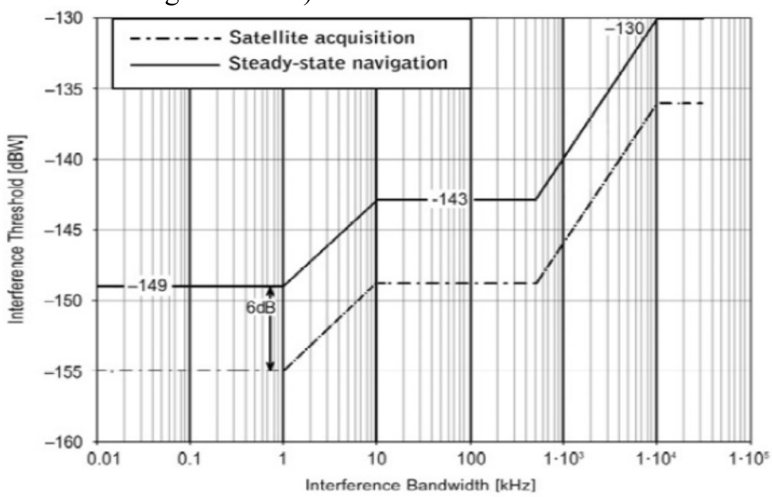

Figure B-18. Interference thresholds versus bandwidth for GLONASS receivers

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ATTACHMENT 6C. 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

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2.11 Use of DME and/or other standard radio navigation aids as an alternative to ILS marker beacons

2.11.1 When DME is used as an alternative to ILS marker beacons, the DME should be located on the airport so that the zero range indication will be a point near the runway. If the DME associated with ILS uses a zero range offset, this facility has to be excluded from RNAV solutions.

2.11.~~2~~1.1 In order to reduce the triangulation error, the DME should be sited to ensure a small angle (e.g. less than 20 degrees) between the approach path and the direction to the DME at the points where the distance information is required.

2.11.~~3~~1.2 The use of DME as an alternative to the middle marker beacon assumes a DME system accuracy of 0.37 km (0.2 NM) or better and a resolution of the airborne indication such as to allow this accuracy to be attained.

2.11.~~4~~1.3 While it is not specifically required that DME be frequency paired with the localizer when it is used as an alternative for the outer marker, frequency pairing is preferred wherever DME is used with ILS to simplify pilot operation and to enable aircraft with two ILS receivers to use both receivers on the ILS channel.

2.11.~~5~~1.4 When the DME is frequency paired with the localizer, the DME transponder identification should be obtained by the "associated" signal from the frequency-paired localizer.

2.11.2 In some locations, the Competent Authority may authorize the use of other means to provide fixes as detailed in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), such as NDB, VOR or GNSS. This may be useful in particular in locations where aircraft user equipage with DME is low, or if the DME is out of service.

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ATTACHMENT 6D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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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 6.3, 6.3.5, for SBAS and Chapter 6.3, 6.3.6, 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-229~~C~~D with Change 1, ~~as amended by United States FAA TSO-C145A/TSO-C146A~~ (or equivalent).

4.2.9 *GLONASS coordinate system*. The GLONASS coordinate system is PZ-90 as described in *Parameters of Earth, 1990 (PZ-90)*, published by the Topographic Service, Russian Federation Ministry of Defence, Moscow.

4.2.9.1 PZ-90 parameters include fundamental geodetic constants, dimensions of the common terrestrial ellipsoid, the characteristics of the gravitational field of the earth, and the elements of the Krasovsky ellipsoid (coordinate system 1942) orientation relative to the common terrestrial ellipsoid.

4.2.9.2 By definition, the coordinate system PZ-90 is a geocentric Cartesian space system whose origin is located at the centre of the earth's body. The Z-axis is directed to the Conventional Terrestrial Pole as recommended by the International Earth Rotation Service. The X-axis is directed to the point of intersection of the earth's equatorial plane and zero meridian established by the Bureau International de l'Heure. The Y-axis completes the right-handed coordinate system.

4.2.9.3 Geodetic reference systems WGS 84 and PZ-90 are maintained consistent with the International Terrestrial Reference Frame (ITRF). While the current conversion parameters from PZ-90 to WGS 84 are provided in Appendix 6B, 3.2.5.2 the application of previous versions of these parameters is also appropriate as long as performance requirements of Chapter 6.3, Table 3.7.2.4-1 for intended operation are met.

4.4 GNSS antenna and receiver

4.4.1 The antenna specifications in Appendix 6B, 3.8, do not control the antenna axial ratio except at boresight. Linear polarization should be assumed for the airborne antenna for GEO signals received at low-elevation angles. For instance, if the minimum elevation angle for which a trackable GEO signal needs to be provided is 5 degrees, the antenna should be presumed to be linearly polarized with −2.5 dBil (−5.5 dBic) gain when receiving this signal. This should be taken into account in the GEO link budget in order to ensure that the minimum received RF signal at the antenna port meets the requirements of Chapter 6.3, 6.3.7.3.4.4.3.2.

4.4.~~1~~2 The failures caused by the receiver can have two consequences on navigation system performance which are the interruption of the information provided to the user or the output of misleading information. Neither of these events are accounted for in the signal-in-space requirement.

4.4.~~2~~3 The nominal error of the GNSS aircraft element is determined by receiver noise, interference, and multipath and tropospheric model residual errors. Specific receiver noise requirements for both the SBAS airborne receiver and the GBAS airborne receiver include the effect of any interference below the protection mask specified in Appendix 6B, 3.7. The required performance has been demonstrated by receivers that apply narrow correlator spacing or code smoothing techniques.

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6.4.1 *Minimum GEO signal power level*. The minimum aircraft equipment (e.g. RTCA/DO-229D with Change 1) is required to operate with a minimum signal strength of –164 dBW at the ~~input of the receiver~~antenna port in the presence of non-RNSS interference (Appendix 6B, 3.7) and an aggregate RNSS noise density of –173 dBm/Hz. In the presence of interference, receivers may not have reliable tracking performance for ~~an input~~a signal strength at the antenna port below –164 dBW (e.g. with GEO satellites placed in orbit prior to 2014). A GEO that delivers a signal power below –164 dBW at the ~~output of the standard~~ receiving antenna port at 5-degree elevation on the ground can be used to ensure signal tracking in a service area contained in a coverage area defined by a minimum elevation angle that is greater than 5 degrees (e.g. 10 degrees). […]

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6.4.3 *SBAS convolutional encoding.* Information on the convolutional coding and decoding of SBAS messages can be found in RTCA/DO-229~~C~~D with Change 1, Appendix 6A.

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6.4.5 S*BAS signal characteristics*. Differences between the relative phase and group delay characteristics of SBAS signals, as compared to GPS signals, can create a relative range bias error in the receiver tracking algorithms. The SBAS service provider is expected to account for this error, as it affects receivers with tracking characteristics within the tracking constraints in Attachment 6D, 8.11. For GEOs for which the on-board RF filter characteristics have been published in RTCA/DO229D with Change 1, Appendix T, the SBAS service providers are expected to ensure that the UDREs bound the residual errors including the maximum range bias errors specified in RTCA/DO229D with Change 1. For other GEOs, the SBAS service providers are expected to work with equipment manufacturers in order to determine, through analysis, the maximum range bias errors that can be expected from existing receivers when they process these specific GEOs. This effect can be minimized by ensuring that the GEOs have a wide bandwidth and small group delay across the pass-band.

6.4.6 *SBAS pseudo-random noise (PRN) codes*. RTCA/DO-229D with Change 1, Appendix 6A, provides two methods for SBAS PRN code generation.

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6.5.1 *SBAS messages*. Due to the limited bandwidth, SBAS data is encoded in messages that are designed to minimize the required data throughput. RTCA/DO-229D with Change 1, Appendix 6A, provides detailed specifications for SBAS messages.

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6.5.4 *Tropospheric function.* Because tropospheric refraction is a local phenomenon, users will compute their own tropospheric delay corrections. A tropospheric delay estimate for precision approach is described in RTCA/DO-229~~C~~D with Change 1, although other models can be used.

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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, except as noted below.

8.11.4.1 For GBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges defined in Table D-11, except that the region 1 minimum bandwidth will increase to 4 MHz and the average correlator spacing is reduced to an average of 0.21 chips or instantaneous of 0.235 chips.

8.11.4.2 For SBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges of the first three regions defined in Table D-11.

…

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

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~~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.~~

(Renumber sections 10.3 – 10.6 to reflect the deletion of section 10.2.)

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10.~~3~~ 2 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.

10.43Out-of-bandinterference 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~~4 Aircraft generated sources

10.~~5~~4.1 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 onboard interference (mainly SATCOM).

10.~~5~~4.2 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 CAR-ANS Part 7.4, 7.4.2.3.5.

10.~~5~~4.3 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~~5 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.

ATTACHMENT 6E. GUIDANCE MATERIAL ON THE PRE-FLIGHT CHECKING OF VOR AIRBORNE EQUIPMENT

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ATTACHMENT 6F. GUIDANCE MATERIAL CONCERNING RELIABILITY AND AVAILABILITY OF RADIOCOMMUNICATIONS AND NAVIGATION AIDS

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ATTACHMENT 6G. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION FOR MLS STANDARDS AND RECOMMENDED PRACTICES

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(Insert the following **new** Attachment H after existing Attachment G.

ATTACHMENT 6H. STRATEGY FOR RATIONALIZATION OF CONVENTIONAL RADIO NAVIGATION AIDS AND EVOLUTION TOWARD SUPPORTING PERFORMANCE BASED NAVIGATION

(see Chapter 6.2, 6.2.1)

1. Introduction

1.1 The shift from facility-referenced navigation to coordinate-based navigation enabled by performance-based navigation (PBN) provides significant benefits, in particular by supplying the flexibility required to design airspace and associated routes and procedures according to operational needs. The most suitable navigation infrastructure to support PBN is GNSS. Consequently, the role of conventional navigation aids is currently evolving towards that of a reversionary terrestrial infrastructure capable of maintaining safety and an adequate level of operations in case of unavailability of GNSS (for example due to outages). During this evolution, terrestrial aids may also enable PBN operations for users not yet equipped with GNSS.

1.2 The aim of the strategy set out in this Attachment is to provide guidance to States to enable both a rationalization of navigation aids as well as a coordinated evolution towards the provision of a reversionary terrestrial infrastructure. This strategy should be considered in particular when deciding on investments into new facilities or on facility renewals. The context of this evolution of navigation infrastructure is described in the *Global Air Navigation Plan* (Doc 9750).

1.3 The strategy addresses the application of radio navigation aids to both conventional and performance based navigation in en-route and terminal airspace, as well as their use as non-precision approach aids. Detailed guidance on PBN navigation infrastructure requirements is available in the *Performance-based Navigation (PBN) Manual* (Doc 9613).

Note.— The strategy relating to approach and landing with vertical guidance (APV) and precision approach and landing operations is contained in attachment 6B.

2. Objectives of the Strategy

The strategy must:

a) maintain at least the current safety level of en-route and terminal area navigation operations;

b) facilitate the implementation of performance based navigation (PBN);

c) maintain global interoperability;

d) provide regional flexibility based on coordinated regional planning;

e) encourage airspace users to equip with appropriate PBN avionics; and

f) take account of economic, operational and technical issues.

3. Considerations

3.1 Operational considerations

3.1.1 The following considerations are based on the assumption that the operational requirements are defined, that the required resources are committed, and that the required effort is applied. In particular, changes in radio navigation facility provision require associated efforts in airspace planning, procedure design, consideration of regulatory aspects and broad consultation with impacted airspace users.

3.2 NDB-related considerations

3.2.1 NDBs serve no role in PBN operation except as a means for position cross-checking and general situational awareness. These minor roles should not lead to the requirement to retain NDB facilities.

3.2.2 Except where no other alternative is available due to constraints in user fleet, financial, terrain or safety limitations:

a) the use of NDBs as en-route navigation aids or terminal area markers is generally obsolete;

b) NDBs used to support SID/STAR should be replaced by RNAV waypoints;

c) NDBs used as locators to assist in ILS intercept operations should be replaced by RNAV waypoints;

d) the use of NDB to support missed approach operations should be discouraged except where local safety cases require a non-GNSS missed approach capability; and

e) NDBs used as a non-precision approach aid should be withdrawn taking the opportunity offered by the implementation of Assembly Resolution 37-11.

3.3 VOR related considerations

3.3.1 The only PBN navigation specification enabled by VOR, provided a co-located DME is present, is RNAV 5. Provision of RNAV 5 based on VOR/DME is subject to significant limitations, since integrated multi-sensor navigation make very little use of VOR/DME, in some cases limiting the range of use to 25NM. Also, only very few aircraft operators have a certified RNAV 5 capability which is based only on VOR/DME. Consequently, the use of VOR/DME to provide PBN services is discouraged. The only exception to this could be to support RNAV 5 routes at or near the bottom of en-route airspace (above minimum sector altitude, MSA) where achieving DME/DME coverage is challenging.

3.3.2 In principle, to enable cost savings, VOR facilities should be withdrawn in the context of an overall PBN plan. No new standalone VOR facilities (e.g., at new locations) should be implemented. However, VORs may be retained to serve the following residual operational purposes:

a) as a reversionary navigation capability (for example for general aviation operations, to assist in avoiding airspace infringements);

b) to provide navigation, cross-checking and situational awareness, especially for terminal area operations (pilot MSA awareness, avoiding premature automatic flight control system arming for ILS intercept, aircraft operational contingency procedures such as engine failure on take-off, missed approaches if required by local safety cases), in particular in areas where low altitude DME/DME coverage is limited;

c) for VOR/DME inertial updating where DME/DME updating is not available;

d) for non-precision approaches as long as users are not equipped for RNP approaches and if no other suitable means of precision approach is available;

e) for conventional SID/STAR to serve non-PBN-capable aircraft;

f) as required to support the operations of State aircraft; and g) to support procedural separation (as detailed in Doc 4444).

3.3.3 In order to provide DME-based RNAV capabilities, those locations which are retained for VOR should normally also be equipped with a co-located DME.

3.3.4 It is expected that adherence to the above principles should enable a decrease of the current number of facilities by 50% or more in areas which support high densities of traffic. To achieve such results, States should develop a rationalization plan, taking into account the service age, all uses and operational roles of their facilities. This normally requires significant coordination with airspace users. The rationalization plan should be an integral part of the PBN implementation plan. Experience has shown that the associated project effort amounts to less expense than the replacement and refurbishment of a single VOR facility. The rationalization planning for VOR is also an important input into the evolution planning for DME.

3.4 DME-related considerations

3.4.1 DME/DME fully supports PBN operations based on the RNAV 1, RNAV 2 and RNAV 5 navigation specifications. Consequently, DME/DME (for equipped aircraft) is the most suitable current terrestrial PBN capability. DME/DME provides a fully redundant capability to GNSS for RNAV applications, and a suitable reversionary capability for RNP applications requiring an accuracy performance of ±1NM (95%) laterally, where supported by an adequate DME infrastructure.

Note.— While some aircraft are certified to provide RNP based on DME/DME, the ability of DME to provide RNP on a general basis is currently under investigation.

3.4.2 States are encouraged to plan the evolution of their DME infrastructure by considering the following:

a) Where a terrestrial navigation reversion capability is required, a DME network capable of supporting DME/DME navigation should be provided, where possible;

b) the DME network design should consider cost savings opportunities whenever possible, such as the withdrawal from a site if an associated VOR is removed, or the possibility to efficiently set up new DME stand-alone sites where other ANSP CNS assets are located;

c) the DME network design should attempt to fill any gaps and provide coverage to as low altitudes as operationally useful without leading to excessive new facilities investments;

d) if satisfactory DME/DME coverage cannot be achieved, States may consider requiring INS equipage from airspace users to bridge gaps in coverage;

e) ANSPs should take maximum advantage of cross-border and military facilities (TACAN), provided the necessary agreements can be put in place; and

f) the frequency assignment of new DME stations should avoid the GNSS L5/E5 band (1 164 – 1 215 MHz) in areas of high DME station density, if possible.

3.4.3 If the above principles are adhered to, it is expected that the density of DME stations in a given area should become more uniform. In other words, the number of facilities in areas of high station density will be reduced, whereas it may need to be increased in areas of low station density.

3.4.4 It is recognized that in some areas, the provision of DME/DME navigation is not possible or practical, such as at very low altitudes, in terrain constrained environments, or on small islands and areas over water. It should also be noted that some FMS exclude the use of ILS-associated DMEs. As a consequence, it is not possible to ensure consistent DME/DME service to all DME/DME equipped users based on ILS-associated DMEs, and thus those facilities cannot be used to provide such service (regardless of whether they are published in the en-route section of the AIP or not).

3.5 Multi-sensor airborne navigation capability considerations

3.5.1 It is recognized that:

a) until all airspace users are both equipped and approved with suitable GNSS-based PBN capabilities, terrestrial navigation aids must be provided either to support conventional procedures or to support DME/DME-based PBN capabilities;

b) once all airspace users are both equipped and approved with suitable GNSS-based PBN capabilities, terrestrial navigation aids may need to be provided to mitigate the risks associated with GNSS outages;

c) it may not be practical or cost-efficient for some airspace users to equip with DME/DME-based and/or INS-based PBN capabilities; and

d) a review of flight plan filings can be an efficient tool to analyze user fleet equipage status; however, actual equipage and approval status may need to be confirmed by the aircraft operator.

3.6 Other considerations

3.6.1 The evolution of terrestrial navigation infrastructure must be accompanied by the development of corresponding operational reversion scenarios. Operational requirements must be balanced with regard to what is possible at reasonable cost, while ensuring safety. In particular, coverage requirements at low altitude can be associated with significant facility cost. Leveraging airspace user capabilities, such as INS, as well as other CNS capabilities (surveillance and communication service coverage and associated ATC capabilities) must be considered to the maximum extent practicable, including common mode failures. In some airspaces, it may not be possible to cater to all airspace user equipage levels and, as a consequence, some airspace users may become subject to operational restrictions.

3.6.2 Some States with a high traffic density environment have identified DME/DME as their main PBN reversion capability (providing either a fully redundant or a degraded level of performance). These States then also plan to provide a residual VOR or VOR/DME infrastructure network to cater to users which have a PBN capability exclusively enabled by GNSS or to those without an adequate PBN capability. Operational procedures associated with the use of such reversion capabilities are under development.

3.6.3 It must be noted that the use of the term “network” in this strategy refers only to navigation facilities assessed on a regional scale, and it does not refer to a network of routes or a particular airspace design. In high-density airspace, it is considered impractical to provide an alternate, conventional back-up route network, once the transition to a fully PBN-based route network has been achieved.

3.6.4 In a few limited cases it may not be possible to provide the same level of benefits through the application of PBN as is possible when using conventional navigation capabilities, due to procedure design limitations or other aspects such as terrain constrained environments. States are invited to bring these cases to the attention of ICAO.

4. Strategy

4.1 Based on the considerations above, the need to consult aircraft operators and international organizations, and to ensure safety, efficiency and cost-effectiveness of the proposed solutions, the global strategy is to:

a) rationalize NDB and VOR and associated procedures;

b) align rationalization planning with equipment lifecycles and PBN implementation planning;

c) replace approaches without vertical guidance with vertically guided approaches;

d) where a terrestrial navigation reversion capability is required, evolve the existing DME infrastructure towards providing a PBN infrastructure complementary to GNSS;

e) provide a residual capability based on VOR (or VOR/DME if possible) to cater to airspace users not equipped with suitable DME/DME avionics, where required; and

f) enable each region to develop an implementation strategy for these systems in line with the global strategy.

— END —

AMENDED REGULATION AFTER REVISION:

CAR-ANS PART 6:

…

6. 2 GENERAL PROVISIONS FOR RADIO NAVIGATION AIDS

6.2.1 Standard radio navigation aids

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Note 2.— It is intended that introduction and application of radio navigation aids to support precision approach and landing operations will be in accordance with the strategy shown in Attachment 6B. It is intended that rationalization of conventional radio navigation aids and evolution toward supporting performance-based navigation will be in accordance with the strategy shown in Attachment 6H.

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6.3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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6.3.1 Specification for ILS

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6.3.1.2 Basic requirements

6.3.1.2.1 The ILS shall comprise the following basic components:

a) VHF localizer equipment, associated monitor system, remote control and indicator equipment;

b) UHF glide path equipment, associated monitor system, remote control and indicator equipment;

c) an appropriate means to enable glide path verification checks.

Note.— The Procedures for Air Navigation Services — Aircraft Operations *(PANS-OPS) (Doc 8168) provide guidance on the conduct of glide path verification checks.*

6.3.1.2.1.1 Distance to threshold information to enable glide path verification checks should be provided by either VHF marker beacons or distance measuring equipment (DME), together with associated monitor systems and remote control and indicator equipment.

6.3.1.2.1.2 If one or more VHF marker beacons are used to provide distance to threshold information, the equipment shall conform to the specifications in 6.3.1.7. If DME is used in lieu of marker beacons, the equipment shall conform to the specifications in 6.3.1.7.6.5.

Note.— Guidance material relative to the use of DME and/or other standard radio navigation aids as an alternative to the marker beacon is contained in Attachment 6C, 6.2.11.

6.3.1.2.1.3 Facility Performance Categories I, II and III — ILS shall provide indications at designated remote control points of the operational status of all ILS ground system components, as follows:

• • •

6.3.1.7 VHF marker beacons

Note.— Requirements relating to marker beacons apply only when one or more marker beacons are Installed.

6.3.1.7.1 *General*

a) There shall be two marker beacons in each installation except where, in the opinion of the Competent Authority, a single marker beacon is considered to be sufficient. A third marker beacon may be added whenever, in the opinion of the Competent Authority, an additional beacon is required because of operational procedures at a particular site.

b) A marker beacons shall conform to the requirements prescribed in 6.3.1.7. When the installation comprises only two marker beacons, the requirements applicable to the middle marker and to the outer marker shall be complied with. When the installation comprises only one marker beacon, the requirements applicable to either the middle or the outer marker shall be complied with. If marker beacons are replaced by DME, the requirements of 6.3.1.7.6.5 shall apply.

c) The marker beacons shall produce radiation patterns to indicate predetermined distance from the threshold along the ILS glide path.

• • •

6.3.1.7.3 *Coverage*

6.3.1.7.3.1 The marker beacon system shall be adjusted to provide coverage over the following distances, measured on the ILS glide path and localizer course line:

a) *inner marker:* 150 m plus or minus 50 m (500 ft plus or minus 160 ft);

b) *middle marker:* 300 m plus or minus 100 m (1 000 ft plus or minus 325 ft);

c) *outer marker:* 600 m plus or minus 200 m (2 000 ft plus or minus 650 ft).

• • •

6.3.1.7.4 *Modulation*

6.3.1.7.4.1 The modulation frequencies shall be as follows:

a) *inner marker:* 3 000 Hz;

b) *middle marker:* 1 300 Hz;

c) *outer marker:* 400 Hz.

• • •

6.3.1.7.5 *Identification*

6.3.1.7.5.1 The carrier energy shall not be interrupted. The audio frequency modulation shall be keyed as follows:

a) *inner marker* 6 dots per second continuously;

b) *middle marker:* a continuous series of alternate dots and dashes, the dashes keyed at the rate of 2 dashes per second, and the dots at the rate of 6 dots per second;

c) *outer marker:* 2 dashes per second continuously.

These keying rates shall be maintained to within plus or minus 15 per cent.

6.3.1.7.6 *Siting*

6.3.1.7.6.1 The inner marker shall be located so as to indicate in low visibility conditions the imminence of arrival at the runway threshold.

6.3.1.7.6.1.1 If the radiation pattern is vertical, the inner marker should be located between 75 m (250 ft) and 450 m (1 500 ft) from the threshold and at not more than 30 m (100 ft) from the extended centre line of the runway.

. . .

6.3.1.7.6.1.1 If the radiation pattern is vertical, the inner marker should be located between 75 m (250 ft) and 450 m (1 500 ft) from the threshold and at not more than 30 m (100 ft) from the extended centre line of the runway.

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6.3.7 Requirements for the Global Navigation Satellite System (GNSS)

6.3.7.1 Definitions

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Antenna port. A point where the received signal power is specified. For an active antenna, the antenna port is a fictitious point between the antenna elements and the antenna pre-amplifier. For a passive antenna, the antenna port is the output of the antenna itself.

Axial ratio. The ratio, expressed in decibels, between the maximum output power and the minimum output power of an antenna to an incident linearly polarized wave as the polarization orientation is varied over all directions perpendicular to the direction of propagation.

. . .

6.3.7.3 GNSS elements specifications

6.3.7.3.1 *GPS Standard Positioning Service (SPS) (L1)*

. . .

6.3.7.3.1.7.4 *Signal power level*. Each GPS satellite shall broadcast SPS navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –158.5 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

. . .

6.3.7.3.2 *GLONASS Channel of Standard Accuracy (CSA) (L1)*

. . .

6.3.7.3.2.5.4 *Signal power level*. Each GLONASS satellite shall broadcast CSA navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

. . .

Note 2.— GLONASS-M satellites will also broadcast a ranging code on L2 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly polarized antenna is not less then –167 dBW for all antenna orientations orthogonal to the direction of propagation.

...

6.3.7.3.4 *Satellite-based augmentation system (SBAS)*

. . .

6.3.7.3.4.4.3 *SBAS satellite-signal power level*

6.3.7.3.4.4.3.1 Each SBAS satellite placed in orbit before 1 January 2014 shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

6.3.7.3.4.4.3.2 Each SBAS satellite placed in orbit after 31 December 2013 shall comply with the following requirements:

a) The satellite shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at or above the minimum elevation angle for which a trackable GEO signal needs to be provided, the level of the received RF signal at the antenna port of the antenna specified in Appendix B, Table B-88, is at least –164.0 dBW.

b) The minimum elevation angle used to determine GEO coverage shall not be less than 5 degrees for a user near the ground.

c) The level of a received SBAS RF signal at the antenna port of a 0 dBic antenna located near the ground shall not exceed –152.5 dBW.

d) The ellipticity of the broadcast signal shall be no worse than 2 dB for the angular range of ±9.1° from boresight.

6.3.7.3.4.4.4 *Polarization.* The broadcast signal shall be right-hand circularly polarized.

. . .

APPENDIX 6B. TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

. . .

3.2.5.2 *CONVERSION BETWEEN PZ-90 AND WGS-84*

3.2.5.2.1 The following conversion parameters should be used to obtain position coordinates in WGS-84 (version G1674) from position coordinates in PZ-90 (Version PZ-90.11):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS\text{-}84} = \begin{bmatrix} 1 & -0.0097 \times 10^{-9} & -0.2036 \times 10^{-9} \\ -0.0097 \times 10^{-9} & 1 & -0.0921 \times 10^{-9} \\ -0.2036 \times 10^{-9} & -0.0921 \times 10^{-9} & 1 \end{bmatrix} \times \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{PZ\text{-}90} \times \begin{bmatrix} 0.003 \\ 0.001 \\ 0 \end{bmatrix}$$

Note 1.— X, Y and Z are expressed in metres. The difference between versions WGS-84 (G1674) and PZ-90 (PZ-90.11) is not significant with respect to operational requirements.

Note 2.— Guidance material on conversion between PZ-90 and WGS-84 is provided in Attachment 6D, section 4.2.9.3.

. . .

3.3.1.3 *Conversion between coordinate systems*. Position information provided by a combined GPS and GLONASS receiver shall be expressed in WGS-84 earth coordinates.

3.3.1.3.1 The GLONASS satellite position, obtained in PZ-90 coordinate frame, should be converted to account for the differences between WGS-84 and PZ-90, as defined in 3.2.5.2.

. . .

3.3.1.4 *GPS/GLONASS time*. When combining measurements from GLONASS and GPS, the difference between GLONASS time and GPS time shall be taken into account.

3.3.1.4.1 GPS/GLONASS receivers shall solve for the time offset between the core constellations as an additional unknown parameter in the navigation solution and not only rely on the time offset broadcast in the navigation messages.

. . .

3.5 Satellite-based augmentation system (SBAS)

. . .

3.5.4.2 *Geostationary orbit (GEO) ranging function parameters.* GEO ranging function parameters shall be as follows:

. . .

User range accuracy (URA): an indicator of the root-mean-square ranging error, excluding atmospheric effects, as described in Table B-26.

Note.— All parameters are broadcast in Type 9 message.

Table B-26. User range accuracy

URA	Accuracy (rms)
0	2 m
1	2.8 m
2	4 m
3	5.7 m
4	8 m
5	11.3 m
6	16 m
7	32 m
8	64 m
9	128 m
10	256 m
11	512 m
12	1 024 m
13	2 048 m
14	4 096 m
15	"Do not use"

Note.— URA values 0 to 14 are not used in the protocols for data application (3.5.5). Airborne receivers will not use the GEO ranging function if URA indicates "Do Not Use"(3.5.8.3).

. . .

3.5.5.4 *Range rate corrections (RRC)*. The range rate correction for satellite *i* is:

$$RRC_i = \begin{cases} \frac{FC_{i,current} - FC_{i,previous}}{t_{i,0f} - t_{i,0f\_previous}}, & \text{if } a_i \neq 0 \\ 0, & \text{if } a_i = 0 \end{cases}$$

where

$FC_{i,current}$ = the most recent fast correction;
$FC_{i,previous}$ = a previous fast correction;
$t_{i,0f}$ = the time of applicability of $FC_{i,current}$;
$t_{i,0f\ previous}$ = the time of applicability of $FC_{i,previous}$; and
a_i = fast correction degradation factor (see Table B-34).

. . .

3.5.5.6.3.1 *Broadcast ionospheric corrections.* If SBAS-based ionospheric corrections are applied, σ^2_{UIRE} is:

$$\sigma^2_{UIRE} = F^2_{pp} \times \sigma^2_{UIVE}$$

where

F_{pp} = (as defined in 3.5.5.5.2);

$$\sigma^2_{UIVE} = \sum_{n=1}^{4} W_n \cdot \sigma^2_{n,ionogrid} \text{ or } \sigma^2_{UIVE} = \sum_{n=1}^{3} W_n \cdot \sigma^2_{n,ionogrid}$$

using the same ionospheric pierce point weights (Wn) and grid points selected for the ionospheric correction (3.5.5.5).

If degradation parameters are used, for each grid point:

$$\sigma^2_{n,ionogrid} = \begin{cases} (\sigma^2_{n,GIVE} + \varepsilon_{iono})^2, & \text{if } RSS_{iono} = 0 \text{ (Type 10 message)} \\ \sigma^2_{n,GIVE} + \varepsilon^2_{iono}, & \text{if } RSS_{iono} = 1 \text{ (Type 10 message)} \end{cases}$$

where

$$\varepsilon_{iono} = C_{iono\_step} \left[\frac{t - t_{iono}}{I_{iono}}\right] + C_{iono\_ramp}(t - t_{iono});$$

t = the current time;
t_{iono} = the time of transmission of the first bit of the ionospheric correction message at the GEO; and
$[x]$ = the greatest integer less than x.

If degradation parameters are not used, for each grid point:

$$\sigma_{n,ionogrid} = \sigma_{n,GIVE}$$

Note.— For GLONASS satellites, both σ_{GIVE} and -ε_{iono} parameters are to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies $(fGLONASS/fGPS)^2$.

. . .

3.5.7.1.2 *SBAS radio frequency monitoring.* The SBAS shall monitor the SBAS satellite parameters shown in Table B-55 and take the indicated action.

. . .

Table B-55. SBAS radio frequency monitoring

Parameter	Reference	Alarm limit	Required action
Signal power level	Chapter 3, 3.7.3..4.4.3	minimum specified power maximum specified power (Note 2)	Cease ranging function (Note 1). Cease broadcast.
Modulation	Chapter 3, 3.7.3.4.4.5	monitor for waveform distortion	Cease broadcast function (Note 1).
SNT-to-GPS time	Chapter 3, 3.7.3.4.5	N/A (Note 3)	Cease ranging function unless σ_{UDRE} reflects error.
Carrier frequency stability	3.5.2.1	N/A (Note 3)	Cease ranging function unless σ_{UDRE} reflects error.
Code/frequency coherence	3.5.2.4	N/A (Note 3)	Cease ranging function unless σ_{UDRE} reflects error.
Maximum code phase deviation	3.5.2.6	N/A (Notes 2 and 3)	Cease ranging function unless σ_{UDRE} reflects error.
Convolutional encoding	3.5.2.9	all transmit messages are erroneous	Cease broadcast.

Notes.—

1. Ceasing the ranging function is accomplished by broadcasting a URA and σ^2_{UDRE} of "Do Not Use" for that SBAS satellite.

2. These parameters can be monitored by their impact on the received signal quality (C/N_0 impact), since that is the impact on the user.

3. Alarm limits are not specified because the induced error is acceptable, provided it is represented in the σ^2_{UDRE} and URA parameters. If the error cannot be represented, the ranging function must cease.

. . .

3.5.7.3.2 *PRN mask and Issue of data — PRN (IODP)*. SBAS shall broadcast a PRN mask and IODP (Type 1 message). The PRN mask values shall indicate whether or not data are being provided for each GNSS satellite. The IODP shall change when there is a change in the PRN mask. The change of IODP in Type 1 messages shall occur before the IODP changes in any other message. The IODP in Type 2 to 5, 7, 24, 25 and 28 messages shall equal the IODP broadcast in the PRN mask message (Type 1 message) used to designate the satellites for which data are provided in that message.

. . .

3.5.7.5.1 *Performance of precise differential correction function*. Given any valid combination of active data, the probability of an out-of-tolerance condition for longer than the relevant time-to-alert shall be less than 2 × 10–7 during any approach, assuming a user with zero latency. The time-to-alert shall be 5.2 seconds for an SBAS that supports precision approach operations, and 8 seconds for an SBAS that supports APV or NPA operations. An out-of-tolerance condition shall be defined as a horizontal error exceeding the HPLSBAS or a vertical error exceeding the VPLSBAS (as defined in 3.5.5.6). When an out-of tolerance condition is detected, the resulting alert message (broadcast in a Type 2 to 5 and 6, 24, 26 or 27 messages) shall be repeated three times after the initial notification of the alert condition for a total of four times in 4 seconds.

. . .

3.5.7.7.2.5 SBAS shall raise an alarm within 5.2 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for precision approach (3.5.7.5.1).

. . .

3.5.7.7.2.6 SBAS shall raise an alarm within 8 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for en-route through APV I (3.5.7.4.1).

Note.— The monitoring applies to all failure conditions, including failures in core satellite constellation(s) or SBAS satellites. This monitoring assumes that the aircraft element complies with the requirements of RTCA/DO-229 with Change 1, except as superseded by 3.5.8 and Attachment 6D, 8.11.

. . .

3.5.8.1 *SBAS-capable GNSS receiver*. Except as specifically noted, the SBAS-capable GNSS receiver shall process the signals of the SBAS and meet the requirements specified in 3.1.3.1 (GPS receiver) and/or 3.2.3.1 (GLONASS receiver). Pseudo-range measurements for each satellite shall be smoothed using carrier measurements and a smoothing filter which deviates less than 0.25 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 0.018 metre per second.

. . .

3.5.8.1.2 *Conditions for use of data*. The receiver shall use data from an SBAS message only if the CRC of this message has been verified. Reception of a Type 0 message from an SBAS satellite shall result in deselection of that satellite for at least one minute and all data from that satellite shall be discarded, except that there is no requirement to discard data from Type 12 and Type 17 messages. For GPS satellites, the receiver shall apply long-term corrections only if the IOD matches both the IODE and 8 least significant bits of the IODC.[…]

3.5.8.1.2.6 The receiver shall apply satellite-specific degradation to the $\sigma_{i,UDRE}^2$ as defined by a Type 28 clock-ephemeris covariance matrix message. The δ_{UDRE} derived from a Type 28 message with an IODP matching that of the PRN mask shall be applied immediately.

3.5.8.1.2.7 In the event of a loss of four successive SBAS messages during an SBAS-based approach operation with a HAL of 40 m or a VAL of 50 m or less, the receiver shall invalidate all UDREI data from that SBAS satellite.

. . .

3.5.8.4.1 *Core satellite constellation(s) ranging accuracy.* The root-mean-square (1 sigma) of the total airborne contribution to the error in a corrected pseudo-range for a GPS satellite at the minimum and maximum received signal power level (Chapter 6.3, 6.3.7.3.1.5.4) under the worst interference environment as defined in 6.3.7 shall be less than or equal to 0.36 metres for minimum signal level and 0.15 metres for maximum signal level, excluding multipath effects, tropospheric and ionospheric residual errors. […]

. . .

3.5.8.4.2 *Precision approach and APV operations*

3.5.8.4.2.1 The receiver shall obtain correction and integrity data for all satellites in the position solution from the same SBAS signal (PRN code).

3.5.8.4.2.2 The receiver shall compute and apply long-term corrections, fast corrections, range rate corrections and the broadcast ionospheric corrections. For GLONASS satellites, the ionospheric corrections received from the SBAS shall be multiplied by the square of the ratio of GLONASS to GPS frequencies $(f_{GLONASS}/f_{GPS})^2$.

3.5.8.4.2.3 The receiver shall use a weighted-least-squares position solution.

3.5.8.4.2.4 The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a 1 sigma deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment 6D, 6.5.4.

3.5.8.4.2.5 The receiver shall compute and apply horizontal and vertical protection levels defined in 3.5.5.6. In this computation, $\sigma_{i,tropo}$ shall be:

$$\frac{1.001}{\sqrt{0.002001 + \sin^2(\theta_i)}} \text{ x } 0.12 \text{ m}$$

where θi is the elevation angle of the i^th satellite.

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

$$\int_{y}^{\infty} f_{ni}(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_{ni}(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

$f_{ni}(x)$ = 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.

3.5.8.4.2.6 The parameters that define the approach path for a single precision approach or APV shall be contained in the FAS data block.

. . .

3.5.8.4.2.6.1 FAS data block parameters shall be as follows (see Table B-57A):

. . .

3.5.8.4.2.6.2 For precision approach and APV operations, the service provider ID broadcast Type 17 message shall be identical to the service provider ID in the FAS data block, except if ID equals 15 in the FAS data block.

Note.— If the service provider ID in the FAS data block equals 15, then any service provider can be used. If the service provider ID in the FAS data block equals 14, then SBAS precise differential corrections cannot be used for the approach.

3.5.8.4.2.6.3 *SBAS FAS data points accuracy.* 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.

3.5.8.4.3 *Departure, en-route, terminal, and non-precision approach operations*

3.5.8.4.3.1 The receiver shall compute and apply long-term corrections, fast corrections and range rate corrections.

3.5.8.4.3.2 The receiver shall compute and apply ionospheric corrections.

Note.— Two methods of computing ionospheric corrections are provided in 3.1.2.4 and 3.5.5.5.2.

3.5.8.4.3.3 The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a standard deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment D, 6.5.4.

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, σ_{tropo} shall be obtained either from the formula in 3.5.8.4.2.5, which can be used for elevation angles not less than 4 degrees, or from the alternate formula below, which can be used for elevation angles not less than2 degrees.

$$\frac{1.001}{\sqrt{0.002001+\sin^2(\theta_i)}} \text{ x } (1+0.015 \text{ x } (\max(0,4-\theta_i))^2) x \text{ } 0.12 \text{ m}$$

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

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

$$\int_{y}^{\infty} f_i(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_i(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where
$f_{ni}(x)$ = 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.

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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)	*0.36 m*	*0.8 m*

. . .

Note 6.— The performance requirements are to be met in the interference environments defined below This defined interference environment is relaxed during initial acquisition of GNSS signals when the receiver cannot take advantage of a steady-state navigation solution to aid signal acquisition.

3.7.2 CONTINUOUS WAVE (CW) INTERFERENCE

3.7.2.1 *GPS AND SBAS RECEIVERS*

3.7.2.1.1 After steady-state navigation has been established, GPS and SBAS receivers 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 dBW at the antenna port.

3.7.2.1.2 During initial acquisition of GPS and SBAS signals prior to steady-state navigation, GPS and SBAS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-83.

Table B-83. CW interference thresholds for GPS and SBAS receivers in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers in steady-state navigation
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 500 MHz	Linearly decreasing from –4.5 dBW to –38 dBW
1 500 MHz < $f_i \leq$ 1 525 MHz	Linearly decreasing from –38 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 After steady-state navigation has been established, GLONASS receivers (except those identified in 3.7.2.2.1.1) 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 –166.5 dBW at the antenna port.

3.7.2.2.1.1 After steady-state navigation has been established, GLONASS receivers used for all phases of flight (excluding those used for the precision approach phase of flight) and put into operation before 1 January 2017 shall meet the performance objectives with CW interfering signals present with a power level at the antenna port 3 dB less than the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level of – 166.5 dBW at the antenna port.

Table B-84. CW interference thresholds for GLONASS receivers in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers in steady-state navigation
$f_i \leq$ 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 During initial acquisition of the GLONASS signals prior to steady-state navigation, GLONASS receivers shall meet the performance objectives with interference thresholds 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 shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 575.42 MHz ±Bw_i/2 and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and shown in Figure B-17 and with the desired signal level of –164 dBW at the antenna port.

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

3.7.3.1.2 During initial acquisition of the GPS and SBAS signals prior to steady-state navigation, GPS and SBAS receivers shall meet the performance objectives with interference thresholds 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 (except those identified in 3.7.3.2.1.1) shall meet the performance objectives while receiving noise-like interfering signals in the frequency band fk ±Bwi/2, with power levels at the antenna port equal to the interference thresholds specified in Table B-86 and shown in Figure B-18 and with a desired signal level of –166.5 dBW at the antenna port.

3.7.3.2.1.1 After steady-state navigation has been established, GLONASS receivers used for all phases of flight (excluding those used for the precision approach phase of flight) and put into operation before 1 January 2017 shall meet the performance objectives while receiving noise-like interfering signals in the frequency band fk ±Bwi/2, with power levels at the antenna port 3 dB less than the interference thresholds specified in Table B-86 and shown in Figure B-18 and with a desired signal level of –166.5 dBW at the antenna port.

Note.— fk is the centre frequency of a GLONASS channel with fk = 1 602 MHz + k × 0.5625 MHz and k = -7 to +6 as defined in Table B-16 and Bwi is the equivalent noise bandwidth of the interference signal.

3.7.3.2.2 During initial acquisition of the GLONASS signals prior to steady-state navigation, the GLONASS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-86.

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

3.8.3.1 The antenna axial ratio shall not exceed 3.0 dB as measured at boresight.

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Table B-85. Interference threshold for band-limited noise-like interference to GPS and SBAS receivers in steady-state navigation

Interference bandwidth	Interference thresholds for receivers in steady-state navigation
0 Hz < Bw_i ≤ 700 Hz	–150.5 dBW
700 Hz < Bw_i ≤ 10 kHz	Linearly increasing from –150.5 to –143.5 dBW
10 kHz < Bw_i ≤ 100 kHz	Linearly increasing from –143.5 to –140.5 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 in steady-state navigation

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 for in-band and near-band	1 575.42 MHz ± 20 MHz	1 592.9525 MHz to 1 609.36 MHz
Interference threshold (Pulse peak power) for in-band and near-band interference	–20 dBW	–20 dBW
Interference threshold (Pulse peak power) outside the in-band and near-band frequency ranges (out-of-band interference)	0 dBW	0 dBW
Pulse width	≤125 µs	≤250 µs
Pulse duty cycle	≤1%	≤1%
Interference signal bandwidth for in-band and near-band interference	≥1 MHz	≥500 kHz

Note 1.— The interference signal is additive white Gaussian noise centred around the carrier frequency and with bandwidth and pulse characteristics specified in the table.
Note 2.— In-band, near-band and out-of-band interference refers to the centre frequency of the interference signal.

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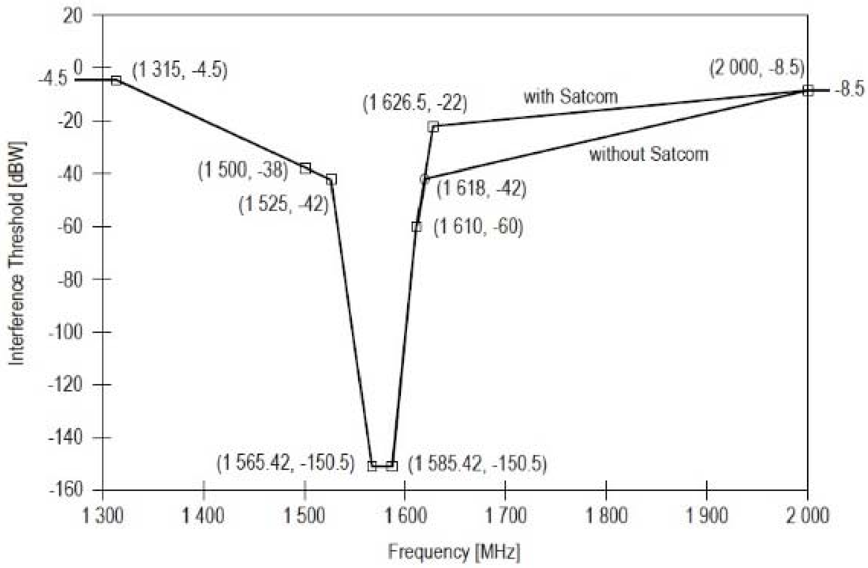

Figure B-15. CW interference thresholds for GPS and SBAS receivers in steady-state navigation

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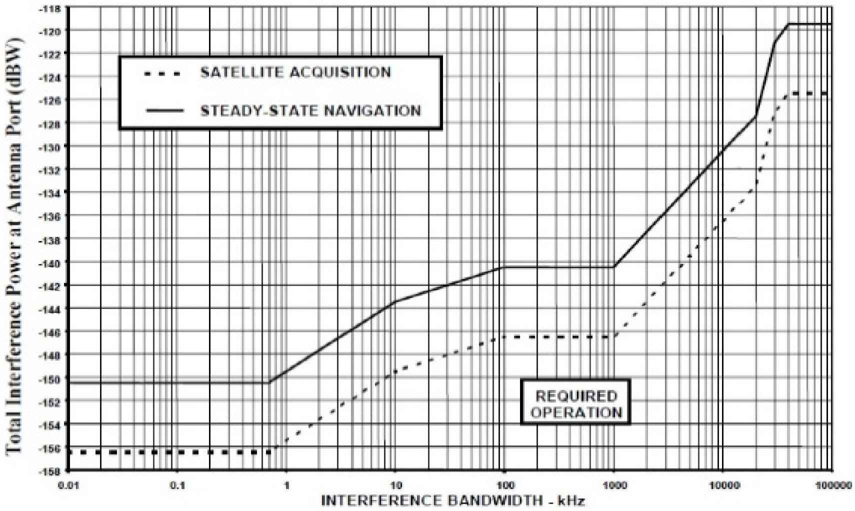

Figure B-17. Interference thresholds versus bandwidth for GPS and SBAS receivers

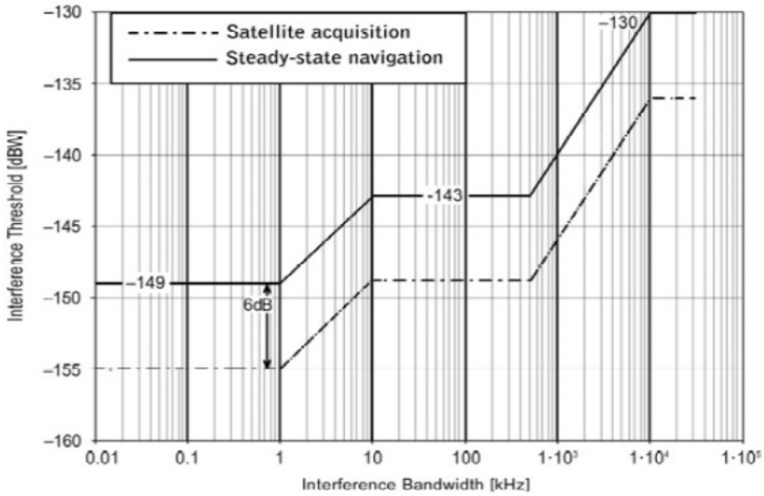

Figure B-18. Interference thresholds versus bandwidth for GLONASS receivers

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ATTACHMENT 6C. 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

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2.11 Use of DME and/or other standard radio navigation aids as an alternative to ILS marker beacons

2.11.1 When DME is used as an alternative to ILS marker beacons, the DME should be located on the airport so that the zero range indication will be a point near the runway. If the DME associated with ILS uses a zero range offset, this facility has to be excluded from RNAV solutions.

2.11.1.1 In order to reduce the triangulation error, the DME should be sited to ensure a small angle (e.g. less than 20 degrees) between the approach path and the direction to the DME at the points where the distance information is required.

2.11.1.2 The use of DME as an alternative to the middle marker beacon assumes a DME system accuracy of 0.37 km (0.2 NM) or better and a resolution of the airborne indication such as to allow this accuracy to be attained.

2.11.1.3 While it is not specifically required that DME be frequency paired with the localizer when it is used as an alternative for the outer marker, frequency pairing is preferred wherever DME is used with ILS to simplify pilot operation and to enable aircraft with two ILS receivers to use both receivers on the ILS channel.

2.11.1.4 When the DME is frequency paired with the localizer, the DME transponder identification should be obtained by the "associated" signal from the frequency-paired localizer.

2.11.2 In some locations, the Competent Authority may authorize the use of other means to provide fixes as detailed in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), such as NDB, VOR or GNSS. This may be useful in particular in locations where aircraft user equipage with DME is low, or if the DME is out of service.

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ATTACHMENT 6D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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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 6.3, 6.3.5, for SBAS and Chapter 6.3, 6.3.6, 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-229D with Change 1, (or equivalent).

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4.2.9 *GLONASS coordinate system*. The GLONASS coordinate system is PZ-90 as described in *Parameters of Earth, 1990 (PZ-90)*, published by the Topographic Service, Russian Federation Ministry of Defence, Moscow.

4.2.9.1 PZ-90 parameters include fundamental geodetic constants, dimensions of the common terrestrial ellipsoid, the characteristics of the gravitational field of the earth, and the elements of the Krasovsky ellipsoid (coordinate system 1942) orientation relative to the common terrestrial ellipsoid.

4.2.9.2 By definition, the coordinate system PZ-90 is a geocentric Cartesian space system whose origin is located at the centre of the earth's body. The Z-axis is directed to the Conventional Terrestrial Pole as recommended by the International Earth Rotation Service. The X-axis is directed to the point of intersection of the earth's equatorial plane and zero meridian established by the Bureau International de l'Heure. The Y-axis completes the right-handed coordinate system.

4.2.9.3 Geodetic reference systems WGS 84 and PZ-90 are maintained consistent with the International Terrestrial Reference Frame (ITRF). While the current conversion parameters from PZ-90 to WGS 84 are provided in Appendix 6B, 3.2.5.2 the application of previous versions of these parameters is also appropriate as long as performance requirements of Chapter 6.3, Table 3.7.2.4-1 for intended operation are met.

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4.4 GNSS antenna and receiver

4.4.1 The antenna specifications in Appendix 6B, 3.8, do not control the antenna axial ratio except at boresight. Linear polarization should be assumed for the airborne antenna for GEO signals received at low-elevation angles. For instance, if the minimum elevation angle for which a trackable GEO signal needs to be provided is 5 degrees, the antenna should be presumed to be linearly polarized with −2.5 dBil (−5.5 dBic) gain when receiving this signal. This should be taken into account in the GEO link budget in order to ensure that the minimum received RF signal at the antenna port meets the requirements of Chapter 6.3, 6.3.7.3.4.4.3.2.

4.4.2 The failures caused by the receiver can have two consequences on navigation system performance which are the interruption of the information provided to the user or the output of misleading information. Neither of these events are accounted for in the signal-in-space requirement.

4.4.3 The nominal error of the GNSS aircraft element is determined by receiver noise, interference, and multipath and tropospheric model residual errors. Specific receiver noise requirements for both the SBAS airborne receiver and the GBAS airborne receiver include the effect of any interference below the protection mask specified in Appendix 6B, 3.7. The required performance has been demonstrated by receivers that apply narrow correlator spacing or code smoothing techniques.

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6.4.1 *Minimum GEO signal power level*. The minimum aircraft equipment (e.g. RTCA/DO-229D with Change 1) is required to operate with a minimum signal strength of –164 dBW at the antenna port in the presence of non-RNSS interference (Appendix 6B, 3.7) and an aggregate RNSS noise density of –173 dBm/Hz. In the presence of interference, receivers may not have reliable tracking performance for a signal strength at the antenna port below –164 dBW (e.g. with GEO satellites placed in orbit prior to 2014). A GEO that delivers a signal power below –164 dBW at the receiving antenna port at 5-degree elevation on the ground can be used to ensure signal tracking in a service area contained in a coverage area defined by a minimum elevation angle that is greater than 5 degrees (e.g. 10 degrees). […]

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6.4.3 *SBAS convolutional encoding.* Information on the convolutional coding and decoding of SBAS messages can be found in RTCA/DO-229D with Change 1, Appendix 6A.

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6.4.5 S*BAS signal characteristics*. Differences between the relative phase and group delay characteristics of SBAS signals, as compared to GPS signals, can create a relative range bias error in the receiver tracking algorithms. The SBAS service provider is expected to account for this error, as it affects receivers with tracking characteristics within the tracking constraints in Attachment 6D, 8.11. For GEOs for which the on-board RF filter characteristics have been published in RTCA/DO229D with Change 1, Appendix T, the SBAS service providers are expected to ensure that the UDREs bound the residual errors including the maximum range bias errors specified in RTCA/DO229D with Change 1. For other GEOs, the SBAS service providers are expected to work with equipment manufacturers in order to determine, through analysis, the maximum range bias errors that can be expected from existing receivers when they process these specific GEOs. This effect can be minimized by ensuring that the GEOs have a wide bandwidth and small group delay across the pass-band.

6.4.6 *SBAS pseudo-random noise (PRN) codes*. RTCA/DO-229D with Change 1, Appendix 6A, provides two methods for SBAS PRN code generation.

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6.5.1 *SBAS messages*. Due to the limited bandwidth, SBAS data is encoded in messages that are designed to minimize the required data throughput. RTCA/DO-229D with Change 1, Appendix 6A, provides detailed specifications for SBAS messages.

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6.5.4 *Tropospheric function.* Because tropospheric refraction is a local phenomenon, users will compute their own tropospheric delay corrections. A tropospheric delay estimate for precision approach is described in RTCA/DO-229D with Change 1, although other models can be used.

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6.11.4 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, except as noted below.

…

8.11.4.1 For GBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges defined in Table D-11, except that the region 1 minimum bandwidth will increase to 4 MHz and the average correlator spacing is reduced to an average of 0.21 chips or instantaneous of 0.235 chips.

8.11.4.2 For SBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges of the first three regions defined in Table D-11.

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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

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10.2 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.

10.3 Out-of-bandinterference 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.

10.4 Aircraft generated sources

10.4.1 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 onboard interference (mainly SATCOM).

10.4.2 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 CAR-ANS Part 7.4, 7.4.2.3.5.

10.4.3 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.

10.5 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.

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ATTACHMENT 6E. GUIDANCE MATERIAL ON THE PRE-FLIGHT CHECKING OF VOR AIRBORNE EQUIPMENT

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ATTACHMENT 6F. GUIDANCE MATERIAL CONCERNING RELIABILITY AND AVAILABILITY OF RADIOCOMMUNICATIONS AND NAVIGATION AIDS

…

ATTACHMENT 6G. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION FOR MLS STANDARDS AND RECOMMENDED PRACTICES

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ATTACHMENT 6H. STRATEGY FOR RATIONALIZATION OF CONVENTIONAL RADIO NAVIGATION AIDS AND EVOLUTION TOWARD SUPPORTING PERFORMANCE BASED NAVIGATION

(see Chapter 6.2, 6.2.1)

1. Introduction

1.1 The shift from facility-referenced navigation to coordinate-based navigation enabled by performance-based navigation (PBN) provides significant benefits, in particular by supplying the flexibility required to design airspace and associated routes and procedures according to operational needs. The most suitable navigation infrastructure to support PBN is GNSS. Consequently, the role of conventional navigation aids is currently evolving towards that of a reversionary terrestrial infrastructure capable of maintaining safety and an adequate level of operations in case of unavailability of GNSS (for example due to outages). During this evolution, terrestrial aids may also enable PBN operations for users not yet equipped with GNSS.

1.2 The aim of the strategy set out in this Attachment is to provide guidance to States to enable both a rationalization of navigation aids as well as a coordinated evolution towards the provision of a reversionary terrestrial infrastructure. This strategy should be considered in particular when deciding on investments into new facilities or on facility renewals. The context of this evolution of navigation infrastructure is described in the *Global Air Navigation Plan* (Doc 9750).

1.3 The strategy addresses the application of radio navigation aids to both conventional and performance based navigation in en-route and terminal airspace, as well as their use as non-precision approach aids. Detailed guidance on PBN navigation infrastructure requirements is available in the *Performance-based Navigation (PBN) Manual* (Doc 9613).

Note.— The strategy relating to approach and landing with vertical guidance (APV) and precision approach and landing operations is contained in attachment 6B.

2. Objectives of the Strategy

The strategy must:

a) maintain at least the current safety level of en-route and terminal area navigation operations;

b) facilitate the implementation of performance based navigation (PBN);

c) maintain global interoperability;

d) provide regional flexibility based on coordinated regional planning;

e) encourage airspace users to equip with appropriate PBN avionics; and

f) take account of economic, operational and technical issues.

3. Considerations

3.1 Operational considerations

3.1.1 The following considerations are based on the assumption that the operational requirements are defined, that the required resources are committed, and that the required effort is applied. In particular, changes in radio navigation facility provision require associated efforts in airspace planning, procedure design, consideration of regulatory aspects and broad consultation with impacted airspace users.

3.2 NDB-related considerations

3.2.1 NDBs serve no role in PBN operation except as a means for position cross-checking and general situational awareness. These minor roles should not lead to the requirement to retain NDB facilities.

3.2.2 Except where no other alternative is available due to constraints in user fleet, financial, terrain or safety limitations:

a) the use of NDBs as en-route navigation aids or terminal area markers is generally obsolete;

b) NDBs used to support SID/STAR should be replaced by RNAV waypoints;

c) NDBs used as locators to assist in ILS intercept operations should be replaced by RNAV waypoints;

d) the use of NDB to support missed approach operations should be discouraged except where local safety cases require a non-GNSS missed approach capability; and

e) NDBs used as a non-precision approach aid should be withdrawn taking the opportunity offered by the implementation of Assembly Resolution 37-11.

3.3 VOR related considerations

3.3.1 The only PBN navigation specification enabled by VOR, provided a co-located DME is present, is RNAV 5. Provision of RNAV 5 based on VOR/DME is subject to significant limitations, since integrated multi-sensor navigation make very little use of VOR/DME, in some cases limiting the range of use to 25NM. Also, only very few aircraft operators have a certified RNAV 5 capability which is based only on VOR/DME. Consequently, the use of VOR/DME to provide PBN services is discouraged. The only exception to this could be to support RNAV 5 routes at or near the bottom of en-route airspace (above minimum sector altitude, MSA) where achieving DME/DME coverage is challenging.

3.3.2 In principle, to enable cost savings, VOR facilities should be withdrawn in the context of an overall PBN plan. No new standalone VOR facilities (e.g., at new locations) should be implemented. However, VORs may be retained to serve the following residual operational purposes:

a) as a reversionary navigation capability (for example for general aviation operations, to assist in avoiding airspace infringements);

b) to provide navigation, cross-checking and situational awareness, especially for terminal area operations (pilot MSA awareness, avoiding premature automatic flight control system arming for ILS intercept, aircraft operational contingency procedures such as engine failure on take-off, missed approaches if required by local safety cases), in particular in areas where low altitude DME/DME coverage is limited;

c) for VOR/DME inertial updating where DME/DME updating is not available;

d) for non-precision approaches as long as users are not equipped for RNP approaches and if no other suitable means of precision approach is available;

e) for conventional SID/STAR to serve non-PBN-capable aircraft;

f) as required to support the operations of State aircraft; and g) to support procedural separation (as detailed in Doc 4444).

3.3.3 In order to provide DME-based RNAV capabilities, those locations which are retained for VOR should normally also be equipped with a co-located DME.

3.3.4 It is expected that adherence to the above principles should enable a decrease of the current number of facilities by 50% or more in areas which support high densities of traffic. To achieve such results, States should develop a rationalization plan, taking into account the service age, all uses and operational roles of their facilities. This normally requires significant coordination with airspace users. The rationalization plan should be an integral part of the PBN implementation plan. Experience has shown that the associated project effort amounts to less expense than the replacement and refurbishment of a single VOR facility. The rationalization planning for VOR is also an important input into the evolution planning for DME.

3.4 DME-related considerations

3.4.1 DME/DME fully supports PBN operations based on the RNAV 1, RNAV 2 and RNAV 5 navigation specifications. Consequently, DME/DME (for equipped aircraft) is the most suitable current terrestrial PBN capability. DME/DME provides a fully redundant capability to GNSS for RNAV applications, and a suitable reversionary capability for RNP applications requiring an accuracy performance of ±1NM (95%) laterally, where supported by an adequate DME infrastructure.

Note.— While some aircraft are certified to provide RNP based on DME/DME, the ability of DME to provide RNP on a general basis is currently under investigation.

3.4.2 States are encouraged to plan the evolution of their DME infrastructure by considering the following:

a) Where a terrestrial navigation reversion capability is required, a DME network capable of supporting DME/DME navigation should be provided, where possible;

b) the DME network design should consider cost savings opportunities whenever possible, such as the withdrawal from a site if an associated VOR is removed, or the possibility to efficiently set up new DME stand-alone sites where other ANSP CNS assets are located;

c) the DME network design should attempt to fill any gaps and provide coverage to as low altitudes as operationally useful without leading to excessive new facilities investments;

d) if satisfactory DME/DME coverage cannot be achieved, States may consider requiring INS equipage from airspace users to bridge gaps in coverage;

e) ANSPs should take maximum advantage of cross-border and military facilities (TACAN), provided the necessary agreements can be put in place; and

f) the frequency assignment of new DME stations should avoid the GNSS L5/E5 band (1 164 – 1 215 MHz) in areas of high DME station density, if possible.

3.4.3 If the above principles are adhered to, it is expected that the density of DME stations in a given area should become more uniform. In other words, the number of facilities in areas of high station density will be reduced, whereas it may need to be increased in areas of low station density.

3.4.4 It is recognized that in some areas, the provision of DME/DME navigation is not possible or practical, such as at very low altitudes, in terrain constrained environments, or on small islands and areas over water. It should also be noted that some FMS exclude the use of ILS-associated DMEs. As a consequence, it is not possible to ensure consistent DME/DME service to all DME/DME equipped users based on ILS-associated DMEs, and thus those facilities cannot be used to provide such service (regardless of whether they are published in the en-route section of the AIP or not).

3.5 Multi-sensor airborne navigation capability considerations

3.5.1 It is recognized that:

a) until all airspace users are both equipped and approved with suitable GNSS-based PBN capabilities, terrestrial navigation aids must be provided either to support conventional procedures or to support DME/DME-based PBN capabilities;

b) once all airspace users are both equipped and approved with suitable GNSS-based PBN capabilities, terrestrial navigation aids may need to be provided to mitigate the risks associated with GNSS outages;

c) it may not be practical or cost-efficient for some airspace users to equip with DME/DME-based and/or INS-based PBN capabilities; and

d) a review of flight plan filings can be an efficient tool to analyze user fleet equipage status; however, actual equipage and approval status may need to be confirmed by the aircraft operator.

3.6 Other considerations

3.6.1 The evolution of terrestrial navigation infrastructure must be accompanied by the development of corresponding operational reversion scenarios. Operational requirements must be balanced with regard to what is possible at reasonable cost, while ensuring safety. In particular, coverage requirements at low altitude can be associated with significant facility cost. Leveraging airspace user capabilities, such as INS, as well as other CNS capabilities (surveillance and communication service coverage and associated ATC capabilities) must be considered to the maximum extent practicable, including common mode failures. In some airspaces, it may not be possible to cater to all airspace user equipage levels and, as a consequence, some airspace users may become subject to operational restrictions.

3.6.2 Some States with a high traffic density environment have identified DME/DME as their main PBN reversion capability (providing either a fully redundant or a degraded level of performance). These States then also plan to provide a residual VOR or VOR/DME infrastructure network to cater to users which have a PBN capability exclusively enabled by GNSS or to those without an adequate PBN capability. Operational procedures associated with the use of such reversion capabilities are under development.

3.6.3 It must be noted that the use of the term “network” in this strategy refers only to navigation facilities assessed on a regional scale, and it does not refer to a network of routes or a particular airspace design. In high-density airspace, it is considered impractical to provide an alternate, conventional back-up route network, once the transition to a fully PBN-based route network has been achieved.

3.6.4 In a few limited cases it may not be possible to provide the same level of benefits through the application of PBN as is possible when using conventional navigation capabilities, due to procedure design limitations or other aspects such as terrain constrained environments. States are invited to bring these cases to the attention of ICAO.

4. Strategy

4.1 Based on the considerations above, the need to consult aircraft operators and international organizations, and to ensure safety, efficiency and cost-effectiveness of the proposed solutions, the global strategy is to:

a) rationalize NDB and VOR and associated procedures;

b) align rationalization planning with equipment lifecycles and PBN implementation planning;

c) replace approaches without vertical guidance with vertically guided approaches;

d) where a terrestrial navigation reversion capability is required, evolve the existing DME infrastructure towards providing a PBN infrastructure complementary to GNSS;

e) provide a residual capability based on VOR (or VOR/DME if possible) to cater to airspace users not equipped with suitable DME/DME avionics, where required; and

f) enable each region to develop an implementation strategy for these systems in line with the global strategy.

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i. ***Separability Clause.*** **-** If, for any reason, any provision of this Memorandum Circular is declared invalid or unconstitutional, the other part or parts thereof which are not affected thereby shall continue to be in full force and effect.

ii. ***Repealing Clause.*** **-** All orders, rules, regulations and issuances, or parts thereof which are inconsistent with this Memorandum Circular are hereby repealed, superseded or modified accordingly.

iii. ***Determination of changes.*** – To highlight the amendments and/or revisions in the Memorandum Circular, the deleted text shall be shown with strikethrough and the new inserted text shall be highlighted with grey shading, as illustrated below:

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

iv. ***Effectivity Clause.*** **-** This Memorandum Circular shall take effect fifteen (15) days after publication in a requisite single newspaper of general circulation or the Official Gazette and a copy filed with the U.P. Law Center - Office of the National Administrative Register.

So Ordered. Signed this __22__ day of __January__ 2017, at the Civil Aviation Authority of the Philippines, MIA Road, Pasay City, Metro Manila, 1301.

CAPTAIN JIM C. SYDIONGCO