Statutory Instrument No. 76 of 2022

CIVIL AVIATION ACT
(Cap. 71:01)

CIVIL AVIATION (RADIO NAVIGATION AIDS) REGULATIONS, 2022

(*Published on 21st June, 2022*)

ARRANGEMENT OF REGULATIONS

REGULATION

25. VHF localizer course alignment accuracy
26. VHF localizer displacement sensitivity
27. VHF localizer voice
28. VHF localizer identification
29. VHF localizer siting
30. VHF localizer monitoring
31. VHF localizer integrity and continuity of service requirements
32. Interference immunity performance for VHF localizer receiving systems

(c) UHF glide path equipment and associated monitor

33. UHF glide path and associated monitor specifications
34. UHF glide path radio frequency
35. UHF glide path coverage
36. UHF glide path structure
37. UHF glide path carrier modulation
38. UHF glide path displacement sensitivity
39. UHF glide path monitoring
40. UHF glide path integrity and continuity of service requirements
41. Localizer and glide path frequency pairing

(d) VHF marker beacons

42. VHF marker beacons
43. VHF marker radio frequency
44. VHF marker coverage
45. VHF marker modulation
46. VHF marker identification
47. VHF marker siting
48. VHF marker monitoring

(e) Precision approach radar system specification

49. Specification for precision approach radar system

(f) The precision approach radar element

50. PAR coverage
51. PAR siting
52. PAR accuracy

(g) The surveillance radar element (SRE)

53. SRE surveillance radar element
54. SRE coverage
55. SRE accuracy

(h) Specifications for VHF omnidirectional radio range (VOR)

56. VHF omni directional range specifications

57. VOR radio frequency
58. VOR polarization and pattern accuracy
59. VOR coverage
60. VOR modulation of navigation signals
61. VOR voice and identification
62. VOR monitoring
63. Interference immunity performance for VOR receiving systems

(i) Non directional radio beacon (NDB) specifications

64. NDB coverage
65. NDB limitations in radiated power
66. NDB radio frequency
67. NDB identification
68. NDB characteristics of emissions
69. NDB siting of locators
70. NDB monitoring

(j) Specification for UHF distance measuring equipment (DME)

71. UHF distance measuring equipment
72. Association of DME with ILS
73. UHF DME performance
74. UHF DME coverage
75. UHF DME accuracy
76. UHF DME radio frequency and polarization
77. UHF DME channeling
78. UHF DME interrogation pulse repetition frequency
79. UHF DME aircraft handling capacity of system
80. UHF DME transponder identification
81. UHF DME identification implementation

(k) Characteristics of transponder and associated monitor

82. DME transponder transmission component
83. DME transponder pulse spacing
84. DME transponder peak power output
85. DME transponder receiver
86. Transponder sensitivity
87. DME transponder load limiting
88. DME transponder noise
89. DME transponder bandwidth
90. DME transponder recovery time
91. DME transponder spurious radiations
92. DME transponder CW and echo suppression
93. DME transponder protection against interference
94. DME transponder decoding
95. DME transponder time delay
96. DME transponder accuracy
97. DME transponder efficiency
98. DME transponder monitoring and control

(l) Technical characteristics of interrogator

99. DME interrogator transmission componen
100. DME interrogator pulse spacing
101. DME interrogator pulse repetition frequency
102. DME interrogator spurious radiation
103. DME interrogator time delay
104. DME interrogator receiver
105. DME interrogator receiver sensitivity
106. DME interrogator and bandwidth
107. DME interrogator interference rejection
108. DME interrogator decoding
109. DME interrogator accuracy

(m) Specification for en-route UHF marker beacons (75 MHz)

110. UHF marker equipment
111. UHF marker characteristics of emissions
112. UHF marker identification
113. UHF marker coverage and radiation pattern
114. UHF marker determination of coverage
115. UHF marker radiation pattern
116. UHF marker monitoring

(n) Requirements for the global navigation satellite system (GNSS)

113. GNSS functions
114. GNSS GNSS elements
115. GNSS space reference
116. GNSS time reference
117. GNSS signal – in – space performance

(o) GPS standard positioning service (SPS) (L1)

118. GPS space and control segment accuracy
119. GPS range domain accuracy
120. GPS availability
121. GPS reliability
122. GPS continuity
123. GPS coverage

(p) Radio frequency (RF) characteristics

124. Carrier frequency
125. GPS Signal spectrum
126. GPS polarization
127. GPS signal power level
128. GPS modulation
129. GPS time
130. GPS coordinate system
131. GPS navigation information

(q) GLONASS channel of standard accuracy (CSA) (L1)

132. GLONASS space and control segment accuracy
133. GLONASS availability
134. GLONASS reliability
135. GLONASS coverage
136. GLONASS carrier frequency
137. GLONASS signal spectrum
138. GLONASS polarization
139. GLONASS signal power level
140. GLONASS modulation
141. GLONASS time
142. GLONASS coordinate System
143. GLONASS navigation information

(r) Aircraft – based augmentation system (ABAS)

144. ABAS performance

(s) Satellite – based augmentation system (SBAS)

145. SBAS performance
146. SBAS functions
147. SBAS ranging
148. SBAS carrier frequency
149. SBAS signal spectrum
150. SBAS satellite signal power level
151. SBAS polarization
152. SBAS modulation
153. SBAS network time (SNT)
154. SBAS navigation information

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

155. GBAS performance
156 GBAS functions
157. GBAS service volume
158. GBAS approach services supporting auto land and guided take-off
159. GBAS positioning service
160. GBAS carrier frequency
161. GBAS access technique
162. GBAS modulation
163. GBAS data broadcast RF field strength and polarization
164. GBAS power transmitted in adjacent channels
165. GBAS unwanted emissions
166. GBAS navigation information
167. Aircraft GNSS receiver
168. GBAS resistance to interference
169. GBAS database

IN EXERCISE of the powers conferred on the Minister of Transport and Public Works by section 89 of the Civil Aviation Act and on the recommendation of the Civil Aviation Authority, the following Regulations are hereby made —

PART I — *Preliminary*

Citation

1. These Regulations may be cited as the Civil Aviation (Radio Navigation Aids) Regulations, 2022.

Interpretation

2. In these Regulations, unless the context otherwise requires —

"aircraft-based augmentation system (ABAS)" means an augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft;

"air navigation services facility" means any facility used, available for use, or designed for use in aid of navigation of aircraft, including airports, landing fields, any structures, mechanisms, lights, beacons, marks, communicating systems, or other instruments or devices used or useful as an aid to the safe taking off, navigation, and landing of aircraft and any combination of such facilities;

"alert" means an indication provided to other aircraft systems or annunciation to the pilot to identify that an operating parameter of a navigation system is out of tolerance;

"alert limit" means the error tolerance not to be exceeded without issuing an alert for a given parameter measurement;

"altitude" means the vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL);

"air navigation services provider" means an entity established for the purpose of providing one or more of the air navigation services as defined in these Regulations;

"angular displacement sensitivity" means the ratio of measured DDM to the corresponding angular displacement from the appropriate reference line;

"antenna port" means 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;

"area navigation" means a method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these;

"Authority" means the Civil Aviation Authority of Botswana established under the Civil Aviation Act; (Cap. 70:01)

"average radius of rated coverage" means the radius of a circle having the same area as the rated coverage;

"axial ratio" means 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;

"back course sector" means the course sector which is situated on the opposite side of the localizer from the runway;

"carrier energy" means the average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle under conditions of no modulation;

"certificate" means the certificate for the provision of Air Navigation Services issued by the Authority under the Civil Aviation (Certification of Air Navigation Services Providers) Regulations, 2021, Statutory No. 144 of 2021;

"channel of standard accuracy" means the specified level of positioning, velocity and timing accuracy that is available to any GLONASS user on a continuous, worldwide basis;

"CNS" means radio navigation aids, communication procedures including those with PANS (Procedures for Air Navigation Services), communication systems, surveillance and collision avoidance systems and aeronautical radio frequency spectrum utilization;

"control motion noise (CMN)" means that portion of the guidance signal error which causes control surface, wheel and column motion and could affect aircraft attitude angle during coupled flight, but does not cause aircraft displacement from the desired course and/or glide path;

"core satellite constellation(s)" means the GPS and GLONASS;

"course line" means the locus of points nearest to the runway centre line in any horizontal plane at which the DDM is zero;

"coupling" means the association of two circuits or systems in such a way that power may be transferred from one to the other;

"course sector" means a sector in a horizontal plane containing the course line and limited by the loci of points nearest to the course line at which the DDM is 0.155;

"displacement sensitivity (localizer)" means the ratio of measured DDM to the corresponding lateral displacement from the appropriate reference line;

"DME" means Distance Measuring Equipment;

"dead time" means a period immediately following the decoding of a valid interrogation during which a received interrogation will not cause a reply to be generated;

"DME/N" means distance measuring equipment, primarily serving operational needs of en-route or Terminal Control Area navigation, where the "N" stands for narrow spectrum characteristics;

"DME/P" means the distance measuring element of the MLS, where the "P" stands for precise distance measurement. The spectrum characteristics are those of DME/N;

"effective adjacent channel rejection" means the rejection that is obtained at the appropriate adjacent channel frequency when all relevant receiver tolerances have been taken into account;

"elevation" means the vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level;

"essential radio navigation service" means a radio navigation service whose disruption has a significant impact on operations in the affected airspace or aerodrome;

"equivalent isotropically radiated power (EIRP)" means the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain);

"Facility Performance category I — ILS" means an ILS which provides guidance information from the coverage limit of the ILS to the point at which the localizer course line intersects the ILS glide path at a height of 60 metres (200 ft) or less above the horizontal plane containing the threshold;

"Facility Performance Category II — ILS" means an ILS which provides guidance information from the coverage limit of the ILS to the point at which the localizer course line intersects the ILS glide path at a height of 15 metres (50 ft) or less above the horizontal plane containing the threshold;

"Facility Performance category III — ILS" means an ILS which, with the aid of ancillary equipment where necessary, provides guidance information from the coverage limit of the facility to, and along, the surface of the runway;

"fan marker beacon" means a type of radio beacon, the emissions of which radiate in a vertical fan-shaped pattern;

"final approach (FA) mode" means the condition of DME/P operation which supports flight operations in the final approach and runway regions;

"front course sector" means the course sector which is situated on the same side of the localizer as the runway;

"GBAS/E" means a ground-based augmentation system transmitting an elliptically-polarized VHF data broadcast;

"GBAS/H" means a ground-based augmentation system transmitting a horizontally-polarized VHF data broadcast;

"global navigation satellite system (GNSS)" means a worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the require navigation performance for the intended operation;

"global navigation satellite system (GLONASS)" means the satellite navigation system operated by the Russian Federation;

"GNSS position error" means the difference between the true position and the position determined by the GNSS receiver;

"ground-based augmentation system (GBAS)" means an augmentation system in which the user receives augmentation information directly from a ground-based transmitter;

"ground-based regional augmentation system (GRAS" means an augmentation system in which the user receives augmentation information directly from one of a group of ground-based transmitters covering a region;

"half course sector" means the sector, in a horizontal plane containing the course line and limited by the loci of points nearest to the course line at which the DDM is 0.0775;

"height" means the vertical distance of a level, a point or an object considered as a point, measured from a specified datum;

"Human Factors Principles" means principles which apply to design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance;

"ILS" means an Instrument Landing System;

"ILS glide path" means that locus of points in the vertical plane containing the runway centre line at which the DDM is zero, which, of all such loci, is the closest to the horizontal plane;

"ILS glide path angle" means the angle between a straight line which represents the mean of the ILS glide path and the horizontal;

"ILS glide path sector" means the sector in the vertical plane containing the ILS glide path and limited by the loci of points nearest to the glide path at which the DDM is 0.175;

"ILS Point "B"" means a point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 1050 metres (3 500 ft) from the threshold;

"initial approach (IA) mode" means the condition of DME/P operation which supports those flight operations outside the final approach region and which is interoperable with DME/N;

"integrity" means a measure of the trust that can be placed in the correctness of the information supplied by the total system and includes the ability of a system to provide timely and valid warnings to the user (alerts);

"key down time" means the time during which a dot or dash of a Morse character is being transmitted;

"LF/MF" means low frequency/medium frequency;

"locator" means an LF/MF NDB used as an aid to final approach; conditions;

"mode X, Y," means a method of coding the DME transmissions by time spacing pulses of a pulse pair, so that each frequency can used more than once;

"NDB" means a radio transmitter at a known location, used as a radio navigation aid;

"path following error (PFE)" means that portion of the guidance signal error which could cause aircraft displacement from the desired course and/or glide path;

"pseudo-range" means the difference between the time of transmission by a satellite and reception by a GNSS receiver multiplied by the speed of light in a vacuum, including bias due to the difference between a GNSS receiver and satellite time reference;

"pulse code" means the method of differentiating between W, X, Y and Z modes and between FA and IA modes;

"pulse decay time" means the time as measured between the 10 and 90 per cent amplitude points on the trailing edge of the pulse envelope;

"pulse duration" means the time interval between the 50 per cent amplitude point on leading and trailing edges of the pulse envelope;

"pulse rise time" means the time as measured between the 10 and 90 per cent amplitude points on the leading edge of the pulse envelope;

"radio navigation service" means a service providing guidance information or position data for the efficient and safe operation of aircraft supported by one or more radio navigation aids;

"rated coverage" means the area surrounding an NDB within which the strength of the vertical field of the ground wave exceeds the minimum value specified for the geographical area in which the radio beacon is situated;

"receiver" means a subsystem that receives GNSS signals and includes one or more sensors;

"reply efficiency" means the ratio of replies transmitted by the transponder to the total of received valid interrogations;

"reserved (bits/words/fields)" means bits/words/fields that are not allocated, but which are reserved for a particular GNSS application;

"search" means the condition which exists when the DME interrogator is attempting to acquire and lock onto the response to its own interrogations from the selected transponder;

"satellite-based augmentation system (SBAS)" means a wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter;

"spare (bits/words/fields)" means bits/words/fields that are not allocated or reserved, and which are available for future allocation;

"standard positioning service (SPS)" means the specified level of positioning, velocity and timing accuracy that is available to any global positioning system (GPS) user on a continuous, worldwide basis;

"Surveillance Radar Element" means a component of a GCA (ground-controlled approach) system —

(*a*) which vectors incoming traffic until it is handed over to the precision approach radar (PAR) controller or established on the ILS (Instrument Landing System);

(*b*) which provides target information in the range and the azimuth while information on target information is not available; and

(*c*) in which a pilot can be vectored onto the final approach so that he or she can be handed over to the PAR controller or can carry out the ILS approach.

"time-to-alert" means the maximum allowable time elapsed from the onset of the navigation system being out of tolerance until the equipment enunciates the alert;

"track" means the condition which exists when the DME interrogator has locked onto replies in response to its own interrogations and is continuously providing a distance measurement;

"touchdown" means the point where the nominal glide path intercepts the runway;

"transmission rate" means the average number of pulse pairs transmitted from the transponder per second;

"two-frequency glide path system" means an ILS glide path in which coverage is achieved by the use of two independent radiation field patterns spaced on separate carrier frequencies within the particular glide path channel;

"VOR" means Very High Frequency (VHF) Omnidirectional radio Range; and

"Z marker beacon" means type of radio beacon, the emissions of which radiate in a vertical cone-shaped pattern.

Application

3. These Regulations shall apply to a person providing Radio Navigation Aids services within designated air space and at aerodromes.

PART II — *General Requirements*

Requirements for radio navigation aids facilities

4. The minimum requirements for planning, installation, commissioning, training, operations and maintenance of the radio navigation aids facilities shall conform to these Regulations.

PART III — *Radio Navigation Aids*

Standard radio navigation aids

5. (1) Standard radio navigation aids to be used for air navigation shall be —

(*a*) the Instrument Landing System (ILS);

(*b*) the Global Navigation Satellite System (GNSS);

(*c*) the VHF Omnidirectional Radio Range (VOR);

(*d*) the Non-Directional Radio Beacon (NDB);

(*e*) the Distance Measuring Equipment (DME);

(*f*) the En-Route VHF Marker Beacon; and

(*g*) microphone landing system (MLS).

(2) Differences in radio navigation aids specified in subregulation (1) shall be published in an Aeronautical Information Publication (AIP).

(3) The ANS shall publish in an (AIP) any radio navigation aid that is not an ILS, but which may be used in whole or in part with aircraft equipment designed for use with an ILS.

GNSS-specific provisions

6. (1) A service provider shall terminate a GNSS satellite service, provided by one of its elements under the Requirements for the Global Navigation Satellite System, on the basis of at least a six-year advance notice.

(2) The Authority shall, upon approving the GNSS-based operations ensure that GNSS data relevant to those operations are recorded.

(3) The Authority shall retain recordings for a period of at least 30 days.

(4) Where the recordings are pertinent to accident and incident investigations, the Authority shall retain such recordings for longer periods until it is evident that they will no longer be required.

Precision approach radar

7. (1) A precision approach radar (PAR) system, where installed and operated as a radio navigation aid together with equipment for two-way communication with aircraft and facilities for the efficient coordination of these elements with air traffic control, shall conform to regulation 49.

(2) Where a radio navigation aid is provided to support precision approach and landing, it shall be supplemented, as necessary, by a source or sources of guidance information which, when used in conjunction with appropriate procedures, will provide effective guidance to, and efficient coupling with, the desired reference path.

Composition of precision approach radar system

8. (1) The precision approach radar system shall comprise the following elements —

(*a*) the Precision Approach Radar element (PAR); and

(*b*) the Surveillance Radar Element (SRE).

(2) Where the Precision Approach Radar only is used, the installation shall be identified by the term "precision approach radar" and not by the term "precision approach radar system".

Specifications for precision approach radar elements

9. The specifications for precision approach radar shall be as contained in Schedule 1.

Specifications for surveillance radar element

10. A surveillance radar used as the SRE of a precision approach radar system shall satisfy the performance requirements as contained in Schedule 1.

Ground and flight testing

11. Radio navigation aids of the types covered by the specifications in regulations 5 to 174 and available for use by aircraft engaged in international air navigation, shall be the subject of periodic ground and flight tests as contained in Schedule 4.

Operational status of radio navigation aids

12. Aerodrome control towers and units providing approach control service shall be provided with information on the operational status of radio navigation services essential for approach, landing and take-off at the aerodrome with which they are concerned, on a timely basis consistent with the use of the service involved.

Power supply for radio navigation aids and communication systems

13. Radio navigation aids and ground elements of communication systems shall be provided with suitable power supplies and means to ensure continuity of service, consistent with the use of the service involved.

Human factor considerations

14. Human factors principles shall be observed in the design and certification of radio navigation aids.

(a) Instrument Landing System

15. (1) The ILS shall comprise the following basic components —

Instrument landing system-composition

(*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; and

(*c*) DME or VHF Markers as a means to enable glide path verification checks.

(2) Distance to threshold information shall be provided by either VHF marker beacons or Distance Measuring Equipment (DME) to enable glide path verification checks together with associated monitor systems and remote control and indicator equipment.

(3) If one or more VHF marker beacons are used to provide distance to threshold information, the equipment shall conform to the specifications in regulations 42 to 48.

(4) 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 —

(*a*) for all Category II and Category III – ILS, the air traffic services unit involved in the control of aircraft on the final approach shall be one of the designated remote control points and shall receive information on the operational status of the ILS, with a delay commensurate with the requirements of the operational environment; and

(*b*) for a Category I - ILS, if that ILS provides an essential radio navigation service, the air traffic services unit involved in the control of aircraft on the final approach shall be one of the designated remote control points and shall receive information on the operational status of the ILS, with a delay commensurate with the requirements of the operational environment.

Basic requirements for instrument landing system-construction and adjustment

16. The ILS shall be constructed and adjusted so that, at a specified distance from the threshold, similar instrumental indications in the aircraft represent similar displacements from the course line or ILS glide path as appropriate, irrespective of the particular ground installation in use.

Localizer and glide path components of facility performance categories.

17. (1) The localizer and glide path components specified in regulation 15 (1) (*a*) and (*b*) which form part of a Facility Performance Category I – ILS shall comply with regulations 20 to 41 respectively, except those in which the application to Facility Performance Category II – ILS is prescribed.

(2) The localizer and glide path components specified in regulation 15 1 (*a*) and (*b*) which form part of a Facility Performance Category II - ILS shall comply with the standards applicable to these components in a Facility Performance Category I – ILS, as supplemented or amended by regulations 20 to 41 in which the application to Facility Performance Category II – ILS is prescribed.

(3) The localizer and glide path components and other ancillary equipment specified in regulation 15 (1) (*a*) and (*b*), which form part of a Facility Performance Category III – ILS, shall otherwise comply with the standards applicable to these components in Facility Performance Categories I and II - ILS, except as supplemented by the standards in regulations 20 to 41 in which application to Facility Performance Category III – ILS is prescribed.

ILS level of safety

18. The ILS shall be so designed and maintained that the probability of operation within the performance requirements specified is of a high value, consistent with the category of operational performance concerned.

Two ILS facilities serving opposite ends of single runway

19. (1) Where two separate ILS facilities serve opposite ends of a single runway, an interlock shall ensure that only the localizer serving the approach direction in use shall radiate, except where the localizer in operational use is Facility Performance Category I – ILS and not operationally harmful interference results.

(2) Where two separate ILS facilities serve opposite ends of a single runway and where a Facility Performance Category I – ILS is to be used for auto-coupled approaches and landings in visual conditions an interlock shall ensure that only the localizer serving the approach direction in use radiates —

provided the other localizer serving the approach direction in use, radiates.

(3) Where ILS facilities serving opposite ends of the same runway or different runways at the same airport, use the same paired frequencies, an interlock shall ensure that only one facility shall radiate at a time.

(4) Where there is a switching from one ILS facility to another, radiation from both facilities shall be suppressed for not less than 20 seconds.

(b) VHF localizer and associated monitor

VHF localizer and associated monitor specifications

20. (1) The specifications of the VHF localizer and associated monitor shall be as set out in Schedule 2.

(2) The radiation from the localizer antenna system shall produce a composite field pattern which is amplitude modulated by a 90 Hz and a 150 Hz tone.

(3) The radiation field pattern shall produce a course sector with one tone predominating on one side of the course and with the other tone predominating on the opposite side.

(4) Where an observer faces the localizer from the approach end of a runway, the depth of modulation of the radio frequency carrier due to the 150 Hz tone shall predominate on the observer's right hand and that due to the 90 Hz tone shall predominate on the observer's left hand.

(5) All horizontal angles employed in specifying the localizer field patterns shall originate from the centre of the localizer antenna system which provides the signals used in the front course sector.

VHF localizer radio frequency

21. (1) The localizer shall —

(*a*) operate in the band 108 MHz to 111.975 MHz; and

(*b*) where a single radio frequency carrier is used, the frequency tolerance shall not exceed 0.005 per cent;

(2) Where two radio frequency carriers are used —

(*a*) the frequency tolerance shall not exceed 0.002 per cent;

(*b*) the nominal band occupied by the carriers shall be symmetrical about the assigned frequency; and

(*c*) with all tolerances applied, the frequency separation between the carriers shall not be less than 5 kHz nor more than 14 kHz.

(3) The emission from the localizer shall —

(*a*) be horizontally polarized; and

(*b*) the vertically polarized component of the radiation on the course line shall not exceed that which corresponds to a DDM error of 0.016 when an aircraft is positioned on the course line and is in a roll attitude of 20 degrees from the horizontal.

(4) For Facility Performance Category II localizers, the vertically polarized component of the radiation on the course line shall not exceed that which corresponds to a DDM error of 0.008 when an aircraft is positioned on the course line and is in a roll attitude of 20 degrees from the horizontal.

(5) For Facility Performance Category III localizers, the vertically polarized component of the radiation within a sector bounded by 0.02 DDM either side of the course line shall not exceed that which corresponds to a DDM error of 0.005 when an aircraft is in a roll attitude of 20 degrees from the horizontal.

(6) For Facility Performance Category III localizers, signals emanating from the transmitter shall contain no components which result in an apparent course line fluctuation of more than 0.005 DDM peak to peak in the frequency band 0.01 Hz to 10 Hz.

VHF localizer coverage

22. (1) The localizer shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation within the localizer and glide path coverage sectors.

(2) The localizer coverage sector shall extend from the centre of the localizer antenna system to distances of —

(*a*) 46.3 km (25 NM) within plus or minus 10 degrees from the front course line;

(*b*) 31.5 km (17 NM) between 10 degrees and 35 degrees from the front course line; and

(*c*) 18.5 km (10 NM) outside of plus or minus 35 degrees from the front course line if coverage is provided.

(2) In all parts of the coverage volume specified in subregulation (1), other than as specified in subregulations (3), (4) and (5), the field strength shall not be less than 40 microvolts (μv) per metre (minus 114 dBW/m^2).

(3) For Facility Performance Category I localizers, the minimum field strength on the ILS glide path and within the localizer course sector from a distance of 18.5 km (10 NM) to a height of 60 m (200 ft) above the horizontal plane containing the threshold shall not be less than 90 μv per metre (minus 107 dBW/m^2).

(4) For Facility Performance Category II localizers, the minimum field strength on the ILS glide path and within the localizer course sector shall —

(*a*) not be less than 100 μv per metre (minus 106 dBW/m^2) at a distance of 18.5 km (10 NM) increasing to not less than 200 μv per metre (minus 100 dBW/m^2); and

(*b*) at a height of 15 m (50 ft) above the horizontal plane containing the threshold.

(5) For Facility Performance Category III localizers, the minimum field strength on the ILS glide path and within the localizer course sector shall —

(*a*) not be less than 100 μv per metre (minus 106 dBW/m^2) at a distance of 18.5 km (10 NM);

(*b*) not increase to less than 200 μv per metre (minus 100 dBW/m^2) at 6 m (20 ft) above the horizontal plane containing the threshold;

(*c*) from this point to a further point 4 m (12 ft) above the runway centre line, and 300 m (1 000 ft) from the threshold in the direction of the localizer; and

(*d*) thereafter at a height of 4 m (12 ft) along the length of the runway in the direction of the localizer, the field strength shall not be less than 100 μv per metre (minus 106 dBW/m^2).

(6) The signals shall be reduced to as low a value as seven degrees.

(7). (1) Where coverage is achieved by a localizer using two radio frequency carriers, one carrier shall provide a radiation field pattern in the front course sector and the other shall provide a radiation field pattern outside that sector.

(2) The ratio of the two carrier signal strengths in space within the front course sector to the coverage limits specified in subregulation (1), shall not be less than 10 dB.

(8) For Facility Performance Category III localizers, the ratio of the two carrier signal strengths in space within the front course sector shall not be less than 16 dB.

VHF localizer course structure

23. (1) For Facility Performance Category I localizers, bends in the course line shall not have amplitudes which exceed the following —

Zone	*Amplitude (DDM) (95% probability)*
Outer limit of coverage to ILS Point "A"	0.031
ILS Point "A" to ILS Point "B"	0.031 at ILS Point "A" decreasing at a linear rate to 0.015 at ILS Point "B"
ILS Point "B" to ILS Point "C"	0.015

(2) For Facility Performance Categories II and III localizers, bends in the course line shall not have amplitudes which exceed the following —

Zone	*Amplitude (DDM) (95% probability)*
Outer limit of coverage to ILS Point "A"	0.031
ILS Point "A" to ILS Point "B"	0.031 at ILS Point "A" decreasing at a linear rate to 0.005 at ILS Point "B"
ILS Point "B" to the ILS reference datum	0.005
and, for Category III only:	
ILS reference datum to ILS Point "D"	0.005
ILS Point "D" to ILS Point "E"	0.005 at ILS Point "D" increasing at a linear rate to 0.010 at ILS Point "E"

VHF localizer carrier modulation

24. (1) The nominal depth of modulation of the radio frequency carrier due to each of the 90 Hz and 150 Hz tones shall be 20 per cent along the course line.

(2) The depth of modulation of the radio frequency carrier due to each of the 90 Hz and 150 Hz tones shall be within the limits of 18 and 22 per cent.

(3) The following tolerances shall be applied to the frequencies of the modulating tones —

(*a*) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 2.5 per cent;

(*b*) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1.5 per cent for Facility Performance Category II installations;

(*c*) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1 per cent for Facility Performance Category III installations;

(*d*) the total harmonic content of the 90 Hz tone shall not exceed 10 per cent;

(*e*) additionally, for Facility Performance Category III localizers, the second harmonic of the 90 Hz tone shall not exceed 5 per cent; and

(*f*) the total harmonic content of the 150 Hz tone shall not exceed 10 per cent.

(4) For Facility Performance Category I – ILS, the modulating tones shall be —

(*a*) 90 Hz; and

(*b*) 150 Hz within plus or minus 1.5 per cent where practicable.

(5). (1) For Facility Performance Category III localizers, the depth of amplitude modulation of the radio frequency carrier at the power supply frequency or its harmonics, or by other unwanted components, shall not exceed 0.5 per cent.

(2) Harmonics of the supply, or other unwanted noise components that may intermodulate with the 90 Hz and 150 Hz navigation tones or their harmonics to produce fluctuations in the course line, shall not exceed 0.05 per cent modulation depth of the radio frequency carrier.

(6) The modulation tones shall be phase-locked so that within the half course sector, the demodulated 90 Hz and 150 Hz wave forms pass through zero in the same direction within —

(*a*) for Facility Performance Categories I and II localizers: 20 degrees; and

(*b*) for Facility Performance Category III localizers: 10 degrees, of phase relative to the 150 Hz component, every half cycle of the combined 90 Hz and 150 Hz wave form.

(7). (1) With two-frequency localizer systems, subregulation (6) shall apply to each carrier and the 90 Hz modulating tone of one carrier shall be phase-locked to the 90 Hz modulating tone of the other carrier so that the demodulated wave forms pass through zero in the same direction —

(*a*) for Categories I and II localizers: 20 degrees; and

(*b*) for Category III localizers: 10 degrees, of phase relative to 90 Hz.

(2) Similarly, the 150 Hz tones of the two carriers shall be phase-locked so that the demodulated wave forms pass through zero in the same direction —

(*a*) for Categories I and II localizers: 20 degrees; and

(*b*) for Category III localizers: 10 degrees, of phase relative to 150 Hz.

(8). (1) The Authority shall authorize the use of alternative two-frequency localizer systems that employ audio phasing different from the normal in-phase conditions described in subregulation (7).

(2) Subject to subregulation (8) the 90 Hz to 90 Hz phasing and the 150 Hz to 150 Hz phasing shall be adjusted to their nominal values to within limits equivalent to those stated in subregulation (7).

(9) The sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall —

(*a*) not exceed 60 per cent; or

(*b*) be less than 30 per cent within the required coverage.

(10) For equipment first installed after 1st January 2000, the sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall —

(*a*) not exceed 60 per cent; or

(*b*) be less than 30 per cent within the required coverage.

(11) When utilizing a localizer for radiotelephone communications, the sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall not exceed —

(*a*) 65 per cent within 10 degrees of the course line; and

(*b*) 78 per cent at any other point around the localizer.

(12) When utilizing a localizer for radiotelephone communications, the sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall —

(*a*) not exceed 65 per cent within 10 degrees of the course line; and

(*b*) not exceed 78 per cent at any other point around the localizer.

(13) Undesired frequency and phase modulation on ILS localizer radio frequency carriers that can affect the displayed DDM values in localizer receivers shall be minimized to such extent as is practical.

VHF localizer course alignment accuracy

25. (1) The mean course line shall be adjusted and maintained within limits equivalent to the following displacements from the runway centre line at the ILS reference datum —

(*a*) for Facility Performance Category I localizers: plus or minus 10.5 m (35 ft), or the linear equivalent of 0.015 DDM, whichever is less;

(*b*) for Facility Performance Category II localizers: plus or minus 7.5 m (25 ft); and

(*c*) for Facility Performance Category III localizers: plus or minus 3 m (10 ft).

VHF localizer displacement sensitivity

26. (1) The nominal displacement sensitivity within the half course sector shall be the equivalent of 0.00145 DDM/m (0.00044 DDM/ft) at the ILS reference datum except that for Category I localizers, where the specified nominal displacement sensitivity cannot be met, the displacement sensitivity shall be adjusted as near as possible to that value.

(2) For Facility Performance Category I localizers on runway codes 1 and 2, the nominal displacement sensitivity shall —

(*a*) be achieved at the ILS Point "B"; and

(*b*) maximum course sector angle shall not exceed six degrees.

(3) The lateral displacement sensitivity shall be adjusted and maintained within the limits of plus or minus —

(*a*) 17 per cent of the nominal value for Facility Performance Categories I and II;

(*b*) 10 per cent of the nominal value for Facility Performance Category III.

(4) For Facility Performance Category II — ILS, displacement sensitivity shall be adjusted and maintained within the limits of plus or minus 10 per cent where practicable.

(5) The increase of DDM shall be substantially linear with respect to angular displacement from the front course line (where DDM is zero), up to an angle on either side of the front course line where the DDM is 0.180.

(6) From that angle to plus or minus 10 degrees, the DDM shall not be less than 0.180 and from plus or minus 10 degrees to plus or minus 35 degrees, the DDM shall not be less than 0.155.

(7) Where coverage is required outside of the plus or minus 35 degrees sector, the DDM in the area of the coverage, except in the back-course sector, shall not be less than 0.155.

VHF localizer voice

27. (1) Facility Performance Categories I and II localizers may provide aground-to-air radiotelephone communication channel to be operated simultaneously with the navigation and identification signals —

Provided that such operation shall not interfere in any way with the basic localizer function.

(2) Category III localizers shall not provide such a radiotelephone communication channel, except where extreme care has been taken in the design and operation of the facility to ensure that there is no possibility of interference with the navigational guidance.

(3) If the radiotelephone communication channel is provided, it shall conform with the following standards —

(*a*) the channel shall be on the same radio frequency carrier or carriers as used for the localizer function, and the radiation shall be horizontally polarized;

(*b*) where two carriers are modulated with speech, the relative phases of the modulations on the two carriers shall be such as to avoid the occurrence of nulls within the coverage of the localizer; and

(c) the peak modulation depth of the carrier or carriers due to the radiotelephone communications shall not exceed 50 per cent but shall be adjusted so that —

(i) the ratio of peak modulation depth due to the radiotelephone communications to that due to the identification signal is approximately 9:1, and

(ii) the sum of modulation components due to use of the radiotelephone channel, navigation signals and identification signals shall not exceed 95 per cent; and

(*d*) the audio frequency characteristics of the radiotelephone communication channel shall be flat to within 3 dB relative to the level at 1 000 Hz over the range 300 Hz to 3 000 Hz.

VHF localizer identification

28. (1) The localizer shall —

(*a*) provide for the simultaneous transmission of an identification signal;

(*b*) be specific to the runway and approach direction, on the same radio frequency carrier or carriers as used for the localizer function; and

(*c*) the transmission of the identification signal shall not interfere in any way with the basic localizer function.

(2) The identification signal shall —

(*a*) be produced by Class A2A modulation of the radio frequency carrier; or

(*b*) carriers using a modulation tone of 1 020 Hz within plus or minus 50 Hz.

(3) The depth of modulation shall be between the limits of 5 and 15 per cent except that where a radiotelephone communication channel is provided, the depth of modulation shall be adjusted so that the ratio of peak modulation depth due to radiotelephone communications to that due to the identification signal modulation is approximately 9:1;

(4) The emissions carrying the identification signal shall —

(*a*) be horizontally polarized; and

(*b*) where two carriers are modulated with identification signals, the relative phase of the modulations shall be such as to avoid the occurrence of nulls within the coverage of the localizer.

(5) The identification signal shall —

(*a*) employ the International Morse Code which consist of two or three letters; or

(*b*) be preceded by the International Morse Code signal of the letter "I", followed by a short pause where it is necessary to distinguish the ILS facility from other navigational facilities in the immediate area.

(6) The identification signal shall —

(*a*) be transmitted by dots and dashes at a speed corresponding to approximately seven words per minute, and;

(*b*) shall be repeated at approximately equal intervals, not less than six times per minute, at all times during which the localizer is available for operational use.

(7) Where the transmissions of the localizer are not available for operational use after removal of navigation components, or during maintenance or test transmissions, the identification signal shall be suppressed and the dots shall have a duration of 0.1 second to 0.160 second.

(8) The dash duration shall —

(*a*) be typically three times the duration of a dot;

(*b*) the interval between dots or dashes shall be equal to that of one dot plus or minus 10 per cent; and

(*c*) the interval between letters shall not be less than the duration of three dots.

VHF localizer siting

29. (1) For Facility Performance Categories II and III —

(*a*) the localizer antenna system shall be located on the extension on the centre line of the runway at the stop end;

(*b*) the equipment shall be adjusted so that the course lines will be in a vertical plane containing the centre line of the runway served; and

(*c*) the antenna height and location shall be consistent with safe obstruction clearance practices.

(2) For Facility Performance Category I, the localizer antenna system shall be located and adjusted as in subregulation (1), unless site constraints dictate that the antenna be offset from the centre line of the runway.

VHF localizer monitoring

30. (1) The automatic monitor system shall provide a warning to the designated control points and cause one of the following to occur, within the period specified in subregulation (5), if any of the conditions stated in subregulation (2) persist —

(*a*) radiation to cease; and

(*b*) removal of the navigation and identification components from the carrier.

(2) The conditions requiring initiation of monitor action shall be the following —

(*a*) for Facility Performance Category I localizers, a shift of the mean course line from the runway centre line equivalent to more than 10.5 m (35 ft), or the linear equivalent to 0.015 DDM, whichever is less, at the ILS reference datum;

(*b*) for Facility Performance Category II localizers, a shift of the mean course line from the runway centre line equivalent to more than 7.5 m (25 ft) at the ILS reference datum;

(*c*) for Facility Performance Category III localizers, a shift of the mean course line from the runway centre line equivalent to more than 6 m (20 ft) at the ILS reference datum;

(*d*) in the case of localizers in which the basic functions are provided by the use of a single-frequency system, a reduction of power output to a level such that any of the requirements of regulation 22, 23 or 24 are no longer satisfied, or to a level that is less than 50 per cent of the normal level (whichever occurs first);

(*e*) in the case of localizers in which the basic functions are provided by the use of a two-frequency system, a reduction of power output for either carrier to less than 80 per cent of normal, except that a greater reduction to between 80 per cent and 50 per cent of normal may be permitted, provided the localizer continues to meet the requirements of regulations 22, 23 and 24; and

(*f*) change of displacement sensitivity to a value differing by more than 17 per cent from the nominal value for the localizer facility.

(3) In the case of localizers in which the basic functions are provided by the use of a two-frequency system, the conditions requiring initiation of monitor action shall include the case where the DDM in the required coverage beyond plus or minus 10 degrees from the front course line, except in the back course sector, decreases below 0.155.

(4) The total period of radiation, including period(s) of zero radiation, outside the performance limits specified in subregulation 2 shall be as short as practicable, consistent with the and need for avoiding interruptions of the navigation service provided by the localizer.

(5) The total period referred to under subregulation (4) shall not exceed under any circumstances —

(*a*) 10 seconds for Category I localizers;

(*b*) 5 seconds for Category II localizers; and

(*c*) 2 seconds for Category III localizers.

(6) Where practicable, the total period under subregulation (5) shall be reduced so as not to exceed two seconds for Category II localizers and one second for Category III localizers.

(7) Design and operation of the monitor system shall be consistent with the requirement that navigation guidance and identification will be removed and a warning provided at the designated remote-control points in the event of failure of the monitor system itself.

VHF localizer integrity and continuity of service requirements

31. (1) The probability of not radiating false guidance signals shall not be less than $1 - 0.5 \times 10^9$ in any one landing for Facility Performance Categories II and III localizers.

(2) The probability of not radiating false guidance signals shall not be less than $1 - 1.0 \times 10^6$ in any one landing for Facility Performance Category I localizers.

(3) The probability of not losing the radiated guidance signal shall be greater than —

(*a*) $1 - 2 \times 10^6$ in any period of 15 seconds for Facility Performance Category II localizers or localizers intended to be used for Category III A operations (equivalent to 2 000 hours mean time between outages); and (*b*) $01 - 2 \times 10^6$ in any period of 30 seconds for Facility Performance Category III localizers intended to be used for the full range of Category III operations (equivalent to 4 000 hours mean time between outages).

(4) The probability of not losing the radiated guidance signal shall exceed $1 - 4 \times 10^6$ in any period of 15 seconds for Facility Performance Category I localizers (equivalent to 1 000 hours mean time between outages).

Interference immunity performance for ILS localizer receiving systems

32. (1) The ILS localizer receiving system shall provide adequate immunity to interference from two-signal, third order inter modulation products caused by VHF FM broadcast signals having levels in accordance with the following —

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

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

and

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

for VHF FM sound broadcasting signals below 107.7 MHz,

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

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VOR receiver input. Neither level shall exceed the desensitization criteria set forth in 1.3.8.2.

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

(2) The ILS localizer receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels in accordance with the following table —

Maximum level of unwanted Frequency signal at receiver input

Frequency (MHz)	*Maximum level of unwanted signal at receiver input (dBm)*
88-102	+15
104	+10
106	+5
107.9	−10

(*c*) *UHF glide path equipment and associated monitor*

UHF glide path and associated monitor specifications

33. (1) The specifications of the UHF glide path and associated monitor shall be as set out in the Schedule 3.

(2) The radiation from the UHF glide path antenna system shall produce a composite field pattern which is amplitude modulated by a —

(*a*) 90 Hz; and

(*b*) a 150 Hz tone.

(3) The composite field pattern shall —

(*a*) be arranged to provide a straight line descent path in the vertical plane containing the centre line of the runway;

(*b*) be the 150 Hz tone predominating below the path:

(*c*) and be 90 Hz tone predominating above the path to at least an angle equal to 1.75 θ.

(4) The ILS glide path angle shall —

(*a*) be three degrees;

(*b*) ILS glide path angles in excess of three degrees shall not be used except where alternative means of satisfying obstruction clearance requirements are impracticable.

(5) The glide path angle shall be adjusted and maintained within —

(*a*) 0.075 θ from θ for Facility Performance Categories I and II — ILS glide paths;

(*b*) 0.04 θ from θ for Facility Performance Category III — ILS glide paths.

(6) The downward extended straight portion of the ILS glide path shall pass through the ILS reference datum at a height ensuring safe guidance over obstructions and also safe and efficient use of the runway served.

(7) The height of the ILS reference datum for Facility Performance Categories II and III — ILS shall be 15 m (50 ft) and a tolerance of plus 3 m (10 ft) is permitted.

(8) The height of the ILS reference datum for Facility Performance Category I — ILS shall be 15 m (50 ft). A tolerance of plus 3 m (10 ft) shall be permitted.

(9) The height of the ILS reference datum for Facility Performance Category I — ILS used on short precision approach runway codes 1 and 2 shall be 12 m (40 ft). A tolerance of plus 6 m (20 ft) is permitted.

UHF glide path radio frequency

34. (1) The glide path equipment shall operate in the band 328.6 MHz to 335.4 MHz where a single radio frequency carrier is used and the frequency tolerance shall not exceed 0.005 per cent.

(2) Where two carrier glide path systems are used —

(*a*) the frequency tolerance shall not exceed 0.002 per cent;

(*b*) the nominal band occupied by the carriers shall be symmetrical about the assigned frequency; and

(*c*) with all tolerances applied, the frequency separation between the carriers shall not be less than 4 kHz nor more than 32 kHz.

(3) The emission from the glide path equipment shall be horizontally polarized.

(4) For Facility Performance Category III — ILS glide path equipment, signals emanating from the transmitter shall contain no components which result in apparent glide path fluctuations of more than 0.02 DDM peak to peak in the frequency band 0.01 Hz to 10 Hz.

UHF glide path coverage

35. (1) The glide path equipment shall provide signals sufficient to allowsatisfactory operation of a typical aircraft installation in sectors of 8 degrees in azimuth on each side of the centre line of the ILS glide path, to a distance of at least 18.5 km (10 NM) up to 1.75 θ and down to 0.45 θ above the horizontal or to such lower angle, down to 0.30 θ, as required to safeguard the promulgated glide path intercept procedure.

(2) In order to provide the coverage for glide path performance specified in subregulation (1) —

(*a*) the minimum field strength within this coverage sector shall be 400 microvolts per metre minus 95 dBW/m2; and

(*b*) for Facility Performance Category I glide paths, this field strength shall be provided down to a height of 30 m (100 ft.) above the horizontal plane containing the threshold.

(3) For Facility Performance Categories II and III glide paths, the field strength shall be provided down to a height of 15 m (50 ft.) above the horizontal plane containing the threshold.

UHF glide path structure

36. (1) For Facility Performance Category I — ILS glide paths, bends in the glide path shall not have amplitudes which exceed the following —

Zone	Amplitude (DDM) (95% probability)
Outer limit of coverage to ILS Point "C"	0.035

(2) For Facility Performance Categories II and III — ILS glide paths, bends in the glide path shall not have amplitudes which exceed the following —

UHF glide path carrier modulation

37. (1) The nominal depth of modulation of the radio frequency carrier due to each of the 90 Hz and 150 Hz tones shall be 40 per cent along the ILS glide path.

(2) The depth of modulation shall not deviate outside the limits of 37.5 per cent to 42.5 per cent.

(3) The following tolerances shall be applied to the frequencies of the modulating tones —

(*a*) the modulating tones shall be 90 Hz and 150 Hz within 2.5 per cent for Facility Performance Category I — ILS;

(*b*) the modulating tones shall be 90 Hz and 150 Hz within 1.5 per cent for Facility Performance Category II — ILS;

(*c*) the modulating tones shall be 90 Hz and 150 Hz within 1 per cent for Facility Performance Category III — ILS;

(*d*) the total harmonic content of the 90 Hz tone shall not exceed 10 per cent and additionally and for Facility Performance Category III equipment, the second harmonic of the 90 Hz tone shall not exceed 5 per cent; and

(*e*) the total harmonic content of the 150 Hz tone shall not exceed 10 per cent.

(4) For Facility Performance Category I — ILS, the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1.5 per cent where practicable.

(5) For Facility Performance Category III glide path equipment, the depth of amplitude modulation of the radio frequency carrier at the power supply frequency or harmonics, or at other noise frequencies, shall not exceed one per cent.

(6) The modulation shall be phase-locked so that within the ILS half glide path sector, the demodulated 90 Hz and 150 Hz wave forms pass through zero in the same direction —

(*a*) for Facility Performance Categories I and II — ILS glide paths: 20 degrees; and

(*b*) for Facility Performance Category III — ILS glide paths: 10 degrees, of phase relative to the 150 Hz component, every half cycle of the combined 90 Hz and 150 Hz wave form.

(7) With two-frequency glide path systems, subregulation (5) shall apply to each carrier and in addition, the 90 Hz modulating tone of one carrier shall be phase-locked to the 90 Hz modulating tone of the other carrier so that the demodulated wave forms pass through zero in the same direction —

(*a*) for Categories I and II — ILS glide paths: 20 degrees;

(*b*) for Category III — ILS glide paths: 10 degrees, of phase relative to 90 Hz; and

(*c*) similarly, the 150 Hz tones of the two carriers shall be phase-locked so that the demodulated wave forms pass through zero in the same direction —

(i) for Categories I and II — ILS glide paths: 20 degrees;

(ii) for Category III — ILS glide paths: 10 degrees, of phase relative to 150 Hz.

(8) The Authority may permit alternative two-frequency glide path systems that employ radio phasing, different from the normal in-phase condition described in subregulation (6).

(9) Where alternate two frequency glide path systems are permitted, the 90 Hz to 90 Hz phasing and the 150 Hz to 150 Hz phasing shall be adjusted to their nominal values to within limits equivalent to those stated in subregulation (6).

(10) Undesired frequency and phase modulation on ILS glide path radio frequency carriers that can affect the displayed DDM values in glide path receivers shall be minimized to such an extent as is practical.

UHF glide path displacement sensitivity

38. (1) For Facility Performance Category I — ILS glide paths, the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at angular displacements above and below the glide path between 0.07 θ and 0.14 θ.

(2) For Facility Performance Category II — ILS glide paths, the angular displacement sensitivity shall be as symmetrical as practicable and the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at an angular displacement of —

(*a*) 0.12 θ below path with a tolerance of plus or minus 0.02 θ; and

(*b*) 0.12 θ above path with a tolerance of plus 0.02 θ and minus 0.05 θ.

(3) For Facility Performance Category III — ILS glide paths —

(*a*) the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875; and

(*b*) at angular displacements above and below the glide path of 0.12 θ with a tolerance of plus or minus 0.02 θ.

(4) The DDM below the ILS glide path shall increase smoothly for decreasing angle until a value of 0.22 DDM is reached.

(5) The value referred to in subregulation (4), shall be achieved at an angle not less than 0.30 θ above the horizontal.

(6) If the DDM below the ILS glide path is achieved at an angle above 0.45 θ, the DDM value shall —

(*a*) not be less than 0.22;

(*b*) at least down to 0.45 θ or to such lower angle; and

(*c*) be down to 0.30 θ, as required to safeguard the promulgated glide path intercept procedure.

(6) The angular displacement sensitivity shall be adjusted and maintained within plus or minus 25 per cent of the nominal value selected, For Facility Performance Category I — ILS glide paths.

(7) The angular displacement sensitivity shall be adjusted and maintained within plus or minus 20 per cent of the nominal value selected, For Facility Performance Category II — ILS glide paths.

(8) The angular displacement sensitivity shall be adjusted and maintained within plus or minus 15 per cent of the nominal value selected, For Facility Performance Category III — ILS glide paths

UHF glide path monitoring

39. (1) The automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the periods specified in subregulation (4) if any of the following conditions persist —

(*a*) shift of the mean ILS glide path angle equivalent to more than minus 0.075 θ to plus 0.10 θ from θ;

(*b*) in the case of ILS glide paths in which the basic functions are provided by the use of a single-frequency system, a reduction of power output to less than 50 per cent of normal —

Provided the glide path continues to meet the requirements of Regulations 35, 36 and 37;

(*c*) the case of ILS glide paths in which the basic functions are provided by the use of two-frequency systems, a reduction of power output for either carrier to less than 80 per cent of normal, except that a greater reduction to between 80 per cent and 50 per cent of normal may be permitted: provided the glide path continues to meet the requirements of Regulations 35, 36 and 37;

(*d*) for Facility Performance Category I — ILS glide paths. A change of the angle between the glide path and the line below the glide path (150 Hz predominating) at which a DDM of 0.0875 is realized by more than the greater of —

(i) plus, or minus 0,0375 θ; or

(ii) an angle equivalent to a change of displacement sensitivity to a value differing by 25 per cent from the nominal value;

(*e*) for Facility Performance Categories II and III — ILS glide paths, a change of displacement sensitivity to a value differing by more than 25 per cent from the nominal value;

(*f*) lowering of the line beneath the ILS glide path at which a DDM of 0.0875 is realized to less than 0.7475 θ from horizontal; and

(*g*) a reduction of DDM to less than 0.175 within the specified coverage below the glide path sector.

(2) Monitoring of the ILS glide path characteristics to smaller tolerances shall be arranged in those cases where operational penalties would otherwise exist.

(3) The total period of radiation, including period(s) of zero radiation, outside the performance limits specified in subregulation (1) shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the ILS glide path.

(4) The total period referred to under subregulation (3), shall not exceed under any circumstances —

(*a*) six seconds for Category I — ILS glide paths; and

(*b*) two seconds for Categories II and III — ILS glide paths.

(5) Where practicable, the total period specified under subregulation (4) for Categories II and III — ILS glide paths, shall not exceed one second.

(6) Design and operation of the monitor system shall be consistent with the requirement that radiation shall cease and a warning shall be provided at the designated remote-control points, in the event of failure of the monitor system.

UHF glide path integrity and continuity of service requirements

40. (1) The probability of not radiating false guidance signals shall not be less than $1 - 0.5 \times 10^9$, in any one landing for Facility Performance Categories II and III glide paths.

(2) The probability of not radiating false guidance signals shall not be less than $1 - 1.0 \times 10^7$ in any one landing for Facility Performance Category I glide paths.

(3) The probability of not losing the radiated guidance signal shall be greater than $1 - 2 \times 10^7$, in any period of 15 seconds for Facility Performance Categories II and III glide paths (equivalent to 2 000 hours mean time between outages).

(4) The probability of not losing the radiated guidance signal, shall exceed $1 - 4 \times 10^6$ in any period of 15 seconds for Facility Performance Category I glide paths (equivalent to 1 000 hours mean time between outages).

41. (1) The pairing of the runway localizer and glide path transmitter frequencies of an instrument landing system shall be taken from the following list in accordance with regulation 35 and the provisions of Statutory Instrument No. 44 Civil Aviation (Radio Frequency Spectrum Utilization) Regulations, 2020.

Localizer and glide path frequency pairing S.I. No. 44 of 2022

Localizer (MHz)	*Glide path (MHz)*	*Localizer (MHz)*	*Glide path (MHz)*
108.1	334.7	110.1	334.4
108.15	334.55	110.15	334.25
108.3	334.1	110.3	335.0
108.35	333.95	110.35	334.85
108.5	329.9	110.5	329.6
108.55	329.75	110.55	329.45
108.7	330.5	110.7	330.2
108.75	330.35	110.75	330.05
108.9	329.3	110.9	330.8
108.95	329.15	110.95	330.65
109.1	331.4	111.1	331.7
109.15	331.25	111.15	331.55
109.3	332.0	111.3	332.3
109.35	331.85	111.35	332.15
109.5	332.6	111.5	332.9
109.55	332.45	111.55	332.75
109.7	333.2	111.7	333.5
109.75	333.05	111.75	333.35
109.9	333.8	111.9	331.1
109.95	333.65	111.95	330.95

(2) In those regions where the requirements for runway localizer and glide path transmitter frequencies of an instrument landing system do not justify more than 20 pairs, they shall be selected sequentially, as required, from the following list —

Sequence number	*Localizer (MHz)*	*Glide path (MHz)*
1	110.3	335.0
2	109.9	333.8
3	109.5	332.6
4	110.1	334.4
5	109.7	333.2
6	109.3	332.0
7	109.1	331.4
8	110.9	330.8
9	110.7	330.2
10	110.5	329.6
11	108.1	334.7
12	108.3	334.1
13	108.5	329.9
14	108.7	330.5
15	108.9	329.3
16	111.1	331.7
17	111.3	332.3
18	111.5	332.9
19	111.7	333.5
20	111.9	331.1

(3) Where existing ILS localizers meeting national requirements are operating on frequencies ending in even tenths of a megahertz, they shall be reassigned frequencies, conforming with regulation 41 or subregulation 2 as soon as practicable and may continue operating on their present assignments only until this reassignment can be effected.

(4) Existing ILS localizers in the international service operating on frequencies ending in odd tenths of a megahertz shall —

(*a*) not be assigned new frequencies ending in odd tenths plus one twentieth of a megahertz; and

(*b*) where, by regional agreement, general use may be made of any of the channels listed in regulation 41 of the Civil Aviation (Radio Frequency Spectrum Utilization) Regulations, 2020.

(d) VHF marker beacon

VHF marker beacons

42. (1) There shall be two marker beacons in each installation except where, in the opinion of the Authority, a single marker beacon is considered to be sufficient.

(2) A third marker beacon may be added whenever, in the opinion of the Authority, an additional beacon is required because of operational procedures at a particular site.

(3) A marker beacon shall conform to the requirements prescribed in regulation 15 to 19 of these Regulations.

(4) Where the installation comprises only two marker beacon, the requirements applicable to the middle marker and to the outer marker shall be complied with.

(5) Where the installation comprises only one marker beacon, the requirements applicable to either the middle or the outer marker shall be complied with and if marker beacons are replaced by DME, the requirements of regulation 47 (10) shall apply.

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

(7) Where a marker beacon is used in conjunction with the back course of a localizer, it shall conform to the marker beacon characteristics specified in regulation 15 to 19 of this Regulations.

(8) Identification signals of marker beacons used in conjunction with the back course of a localizer shall be clearly distinguishable from the inner, middle and outer marker beacon identifications, as prescribed in regulation 46.

VHF marker radio frequency

43. The marker beacons shall operate at 75 MHz with a frequency tolerance of plus or minus 0.005 per cent and shall utilize horizontal polarization.

VHF marker coverage

44. (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); and

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

VHF marker modulation

45. (1) The modulation frequencies shall be as follows —

(*a*) inner marker: 3 000 Hz;

(*b*) middle marker: 1 300 Hz; and

(*c*) outer marker: 400 Hz.

(2) The frequency tolerance of the above frequencies shall be plus or minus 2.5 per cent, and the total harmonic content of each of the frequencies shall not exceed 15 per cent.

(3) The depth of modulation of the markers shall be 95 per cent plus or minus 4 per cent.

VHF marker identification

46. A carrier energy shall not be interrupted and 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; and

(*c*) outer marker: 2 dashes per second continuously. These keying rates shall be maintained to within plus or minus 15 per cent.

VHF marker siting

47. (1) An inner marker shall be located so as to indicate in low visibility conditions the imminence of arrival at the runway threshold.

(2) If the radiation pattern is vertical, the inner marker, when installed, shall 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.

(3) If the radiation pattern is other than vertical, the equipment shall be located so as to produce a field within the course sector and ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern and located as prescribed in subregulation (2).

(4) The middle marker shall be located so as to indicate the imminence, in low visibility conditions, of visual approach guidance.

(5) Where the radiation pattern is vertical, the middle marker shall be located 1050 m (3 500 ft) plus or minus 150 m (500 ft), from the landing threshold at the approach end of the runway and at not more than 75 m (250 ft) from the extended centre line of the runway.

(6) Where the radiation pattern is other than vertical, the equipment shall be located so as to produce a field within the course sector and ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern and located as prescribed in subregulation (5).

(7) The outer marker shall be located so as to provide height, distance and equipment functioning checks to aircraft on intermediate and final approach.

(8) The outer marker shall be located 7.2 km (3.9 NM) from the threshold except that, where for topographical or operational reasons this distance is not practicable, the outer marker may be located between 6.5 and 11.1 km (3.5 and 6 NM) from the threshold.

(9) Where the radiation pattern is vertical, the outer marker shall not be more than 75 m (250 ft) from the extended centre line of the runway.

(10) Where the radiation pattern is not vertical, the equipment shall —

(*a*) be located so as to produce a field within the course sector; and

(*b*) shall have an ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern.

(11). The positions of marker beacons, or where applicable, the equivalent distance(s) indicated by the DME when used as an alternative to part or all of the marker beacon component of the ILS shall be published in accordance with the provisions of Civil Aviation (Aeronautical Information Services) regulation, 2020.

(12) When so used, the DME shall provide distance information operationally equivalent to that furnished by marker beacon(s).

(13) When used as an alternative for the middle marker, the DME shall be frequency paired with the ILS localizer and sited so as to minimize the error in distance information.

(14) The DME reffered to in subregulation (10) shall conform to the specification in regulation 71 to 81.

VHF marker monitoring

48. (1) Suitable equipment shall provide signals for the operation of an automatic monitor and the monitor shall transmit a warning to a control point if either of the following conditions arise —

(*a*) failure of the modulation or keying; and

(*b*) reduction of power output to less than 50 per cent of normal.

(2) For each marker beacon, suitable monitoring equipment shall be provided which will indicate at the appropriate location a decrease of the modulation depth below 50 per cent.

(e) Specification for precision approach radar system

Specification for precision approach radar system

49. (1) The precision approach radar system shall comprise the following elements —

(*a*) the precision approach radar element (PAR); and

(*b*) the surveillance radar element (SRE).

(2) Where the PAR only is used, the installation shall be identified by the term PAR or precision approach radar and not by the term "precision approach radar system".

(f) The precision approach radar element (PAR)

PAR coverage

50. The PAR shall be capable of detecting and indicating the position of an aircraft of $15m^2$ echoing area or larger, which is within a space bounded by a 20-degree azimuth sector and a 7-degree elevation sector, to a distance of at least 16.7 km (9 NM) from its respective antenna.

PAR siting

51. The PAR shall be sited and adjusted so that it gives complete coverage of a sector with its apex at a point 150 m (500 ft) from the touchdown in the direction of the stop end of the runway and extending plus or minus 5 degrees about the runway centre line in azimuth and from minus 1 degree to plus 6 degrees in elevation.

PAR accuracy

52 (1) Azimuth information shall be displayed in such a manner that —

(*a*) left-right deviation from the on-course line shall be easily observable;

(*b*) the maximum permissible error with respect to the deviation from the on-course line shall be either 0.6 per cent of the distance from the PAR antenna plus 10 per cent of the deviation from the on-course line or 9 m (30 ft), whichever is greater;

(*c*) the equipment shall be so sited that the error at the touchdown shall not exceed 9 m (30 ft) and the equipment shall be so aligned and adjusted that the displayed error at the touchdown shall be a minimum and shall not exceed 0.3 per cent of the distance from the PAR antenna or 4.5 m (15 ft), whichever is greater; and

(*d*) it shall be possible to resolve the positions of two aircraft which are at 1t degrees in azimuth of one another.

(2) Elevation information shall be displayed in such a manner that —
(*a*) up-down deviation from the descent path for which the equipment is set shall be easily observable;
(*b*) the maximum permissible error with respect to the deviation from the on-course line shall be 0.4 per cent of the distance from the PAR antenna plus 10 per cent of the actual linear displacement from the chosen descent path or 6 m (20 ft), whichever is greater;
(*c*) the equipment shall be so sited that the error at the touchdown shall not exceed 6 m (20 ft) and the equipment shall be so aligned and adjusted that the displayed error at the touchdown shall be a minimum and shall not exceed 0.2 per cent of the distance from the PAR antenna or 3 m (10 ft), whichever is greater; and
(*d*) it shall be possible to resolve the positions of two aircraft that are at 0.6 degree in elevation of one another.
(3) The error in indication of the distance from the touchdown shall —
(*a*) not exceed 30 m (100 ft) plus 3 per cent of the distance from the touchdown; and
(*b*) be possible to resolve the positions of two aircraft which are at 120 m (400 ft) of one another on the same azimuth.
(4) Information shall —
(*a*) be made available to permit the position of the controlled aircraft to be established with respect to other aircraft and obstructions;
(*b*) also permit appreciation of ground speed and rate of departure from or approach to the desired flight path; and
(*c*) be completely renewed at least once every second.

(*g*) *The surveillance radar element (SRE)*

The surveillance radar element (SRE)

53. A surveillance radar used as the SRE of a precision approach radar system shall satisfy at least the following broad performance requirements.

SRE coverage

54. (1) The SRE shall be capable of detecting aircraft of 15m^2 echoing area and larger, which are in line of sight of the antenna within a volume described as follows —

The rotation through 360 degrees about the antenna of a vertical plane surface bounded by a line at an angle of 0.5 degrees above the horizontal plane of the antenna, extending from the antenna to 46.3 km (25 NM);
(*a*) by a vertical line at 46.3 km (25 NM) from the intersection with the 0.5-degree line up to 3 000 m (10 000 ft) above the level of the antenna;
(*b*) by a horizontal line at 3 000 m (10 000 ft) from 46.3 km (25 NM) back towards the antenna to the intersection with a line from the antenna at 20 degrees above the horizontal plane of the antenna; and
(*c*) and by a 30-degree line from the intersection with the 3 000 m (10 000 ft) line to the antenna.

SRE accuracy

55. (1) The indication of position in azimuth shall —
(*a*) be within plus or minus two degrees of the true position; and
(*b*) be possible to resolve the positions of two aircraft which are at four degrees of azimuth of one another.
(2) The error in distance indication shall —
(*a*) not exceed five per cent of true distance or 150 m (500 ft), whichever is the greater; and

(*b*) shall be possible to resolve the positions of two aircraft that are separated by a distance of 1 per cent of the true distance from the point of observation or 230 m (750 ft), whichever is the greater.

(3) The error in distance indication shall not exceed 3 per cent of the true distance or 150 m (500 ft), whichever is the greater.

(4) The equipment shall be capable of completely renewing the information concerning the distance and azimuth of any aircraft within the coverage of the equipment at least once every four seconds.

(5) Efforts shall be made to reduce, as far as possible, the disturbance caused by ground echoes or echoes from clouds and precipitation.

(h) Specification for VHF Omnidirectional Radio Range (VOR)

VHF omnidirectionl radio range (VOR)

56. (1) The VOR shall —

(*a*) be constructed and adjusted so that similar instrumental indications in aircraft represent equal clockwise angular deviations (bearings), degree for degree from magnetic North as measured from the location of the VOR; and

(*b*) radiate a radio frequency carrier with which are associated two separate 30 Hz modulations.

(2) Subject to subregulation (1) —

(*a*) these modulations shall be such that its phase is independent of the azimuth of the point of observation (reference phase); and

(*b*) the other modulation (variable phase) shall be such that its phase at the point of observation differs from that of the reference phase by an angle equal to the bearing of the point of observation with respect to the VOR.

VOR radio frequency

57. (1) The VOR shall —

(*a*) operate in the band 111.975 MHz to 117.975 MHz; and

(*b*) operate in frequencies in the band 108 MHz to 111.975 MHz in accordance with the provisions of the Civil Aviation (Radio Frequency Spectrum Utilization) Regulations, regulations 35 and 36 (4).

(2) The highest assignable frequency shall —

(*a*) be 117.950 MHz and the channel separation shall be in increments of 50 kHz referred to the highest assignable frequency; and

(*b*) in areas where 100 kHz or 200 kHz channel spacing is in general use, the frequency tolerance of the radio frequency carrier shall be plus or minus 0.005 per cent.

(3) The frequency tolerance of the radio frequency carrier of all new installations implemented after 23 May 1974 in areas where 50 kHz channel spacing is in use, shall be plus or minus 0.002 per cent.

(4) In areas where new VOR installations are implemented and are assigned frequencies spaced at 50 kHz from existing VORs in the same area, priority shall be given to ensuring that the frequency tolerance of the radio frequency carrier of the existing VORs is reduced to plus or minus 0.002 per cent.

VOR polarization and pattern a ccuracy

58. (1) The emission from the VOR shall —

(*a*) be horizontally polarized; and

(*b*) the vertically polarized component of the radiation shall be as small as possible.

(2) The ground station contribution to the error in the bearing information conveyed by the horizontally polarized radiation from the VOR for all elevation angles between 0 and 40 degrees, measured from the centre of the VOR antenna system, shall be within plus or minus 2 degrees.

VOR coverage

59. (1) The VOR shall provide signals such as to permit satisfactory operation of a typical aircraft installation at the levels and distances required for operational reasons, and up to an elevation angle of 40 degrees.

(2) The field strength or power density in space of VOR signals required to permit satisfactory operation of a typical aircraft installation at the minimum service level at the maximum specified service radius shall be 90 microvolts per metre or minus 107 dBW/m^2.

VOR modulations of navigation signals

60. (1) The radio frequency carrier as observed at any point in space shall be amplitude modulated by two signals as follows —

(*a*) subcarrier of 9 960 Hz of constant amplitude, frequency modulated at 30 Hz —

(i) for the conventional VOR, the 30 Hz component of this FM subcarrier is fixed without respect to azimuth and is termed the "reference phase" and shall have a deviation ratio of 16 plus or minus 1, and

(ii) for the Doppler VOR, the phase of the 30 Hz component varies with azimuth and is termed the "variable phase" and shall have a deviation ratio of 16 plus or minus 1 when observed at any angle of elevation up to 5 degrees, with a minimum deviation ratio of 11 when observed at any angle of elevation above 5 degrees and up to 40 degrees; and

(*b*) a 30 Hz amplitude modulation component —

(i) for the conventional VOR, this component results from a rotating field pattern, the phase of which varies with azimuth, and is termed the "variable phase", and

(ii) for the Doppler VOR, this component, of constant phase with relation to azimuth and constant amplitude, is radiated Omni directionally and is termed the "reference phase".

(2) The nominal depth of modulation of the radio frequency carrier due to the 30 Hz signal or the subcarrier of 9 960 Hz shall be within the limits of 28 per cent and 32 per cent.

(3) The depth of modulation of the radio frequency carrier due to the 30 Hz signal, as observed at any angle of elevation up to 5 degrees, shall be within the limits of 25 to 35 per cent.

(4) The depth of modulation of the radio frequency carrier due to the 9 960 Hz signal, as observed at any angle of elevation up to five degrees, shall be within the limits of 20 to 55 per cent on facilities without voice modulation, and within the limits of 20 to 35 per cent on facilities with voice modulation.

(5) The variable and reference phase modulation frequencies shall be 30 Hz within plus or minus 1 per cent.

(6) The subcarrier modulation mid-frequency shall be 9 960 Hz within plus or minus one per cent.

(7) Percentage of amplitude modulation for the —

(*a*) the conventional VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed five per cent;

(*b*) Doppler VOR, the percentage of amplitude modulation of the 9960 Hz subcarrier shall not exceed 40 percent when measured at a point at least 300 m (1 000 ft) from the VOR.

(8) Where 50 kHz VOR channel spacing is implemented, the sideband level of the harmonics of the 9 960 Hz component in the radiated signal shall not exceed the following levels referred to the level of the 9 960 Hz sideband —

VOR voice and identification

61. (1) Where the VOR provides a simultaneous communication channel ground-to air, it shall be on the same radio frequency carrier as used for the navigational function.

(2) The radiation on the simultaneous communications channel shall be horizontally polarized.

(3) The peak modulation depth of the carrier on the simultaneous communication channel shall not be greater than 30 per cent.

(4) The audio frequency characteristics of the speech channel shall be within 3 dB relative to the level at 1000 Hz over the range 300 Hz to 3000 Hz.

(5) The VOR shall provide for the simultaneous transmission of a signal of identification on the same radio frequency carrier as that used for the navigational function.

(6) The identification signal radiation shall —

(*a*) be horizontally polarized; and

(*b*) the identification signal shall employ the International Morse Code and consist of two or three letters and shall be sent at a speed corresponding to approximately seven words per minute.

(7) The identification signal shall be repeated at least once every 30 seconds and the modulation tone shall be 1020 Hz within plus or minus 50 Hz.

(8) The identification signal shall be transmitted at least three times each 30 seconds, spaced equally within that time period.

(9) One of these identification signals may take the form of a voice identification.

(10) The depth to which the radio frequency carrier is modulated by the code identification signal shall be close to, but not in excess of 10 per cent: Provided that, where a communication channel is not provided, it shall be permissible to increase the modulation by the code identification signal to a value not exceeding 20 per cent.

(11) Where the VOR provides a simultaneous communication channel ground-to- air, the modulation depth of the code identification signal shall be five plus or minus one per cent in order to provide a satisfactory voice quality.

(12) The transmission of speech shall —

(*a*) not interfere in any way with the basic navigational function; and

(*b*) when speech is being radiated, the code identification shall not be suppressed.

(13) The VOR receiving function shall permit positive identification of the wanted signal under the signal conditions encountered within the specified coverage limits, and with the modulation parameters specified at subregulation (5), (6) and (7).

VOR monitoring

62. (1) Suitable equipment located in the radiation field shall provide signals for the operation of an automatic monitor.

(2) The monitor shall transmit a warning to a control point, and either remove the identification and navigation components from the carrier or cause radiation to cease if any one or a combination of the following deviations from established conditions arises —

(*a*) change in excess of one degree at the monitor site of the bearing information transmitted by the VOR; and

(*b*) a reduction of 15 per cent in the modulation components of the radio frequency signals voltage level at the monitor of either the subcarrier, or 30 Hz amplitude modulation signals, or both.

(3) Failure of the monitor itself shall transmit a warning to a control point and either —

(*a*) remove the identification and navigation components from the carrier; or

(*b*) cause radiation to cease.

Interference immunity performance for VOR receiving systems

63. (1) The VOR receiving system shall provide adequate immunity to interference from two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels in accordance with the following —

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

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

and

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

for VHF FM sound broadcasting signals below 107.7 MHz.

(2) Where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order inter modulation product on the desired VOR frequency.

(3) N^2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VOR receiver input and neither level shall exceed the desensitization criteria set forth in subregulation (2).

(4) $\Delta f = 108.1 - f^1$, where f^1 is the frequency of N^1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

(5) The VOR receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels in accordance with the following table —

Frequency (MHz)	Maximum level of unwanted signal at receiver input (dBm)
88-102	+15
104	+10
106	+5
107.9	-10

(i) Specification for non-directional radio beacon (NDB)

NDB coverage

64. (1) The minimum value of field strength in the rated coverage of an NDB shall be 70 microvolts per metre.

(2) All notifications or promulgations of NDBs shall be based upon the average radius of the rated coverage.

(3) Where the rated coverage of an NDB is materially different in various operationally significant sectors, its classification shall be expressed in terms of the average radius of rated coverage and the angular limits of each sector as follows —

(*a*) radius of coverage of sector/angular limits of sector expressed as magnetic bearing clockwise from the beacon; and (*b*) where it is desirable to classify an NDB in such a manner, the number of sectors shall be kept to a minimum and preferably shall not exceed two.

NDB limitations in radiated power

65. The power radiated from an NDB shall not exceed by more than 2 dB than necessary to achieve its agreed rated coverage, except that this power may be increased if coordinated regionally or if no harmful interference to other facilities will result.

NDB radio frequencies

66. (1) The radio frequencies assigned to NDBs shall be selected from those available in that portion of the spectrum between 190 kHz and 1 750 kHz.

(2) The frequency tolerance applicable to NDBs shall be 0.01 per cent except that, for NDBs of antenna power above 200 W using frequencies of 1 606.5 kHz and above, the tolerance shall be 0.005 per cent.

(3) Where two locators are used as supplements to an ILS, the frequency separation between the carriers of the two shall be not less than 15 kHz to ensure to correct operation of the radio compass, and preferably not more than 25 kHz in order to permit a quick tuning shift in cases where an aircraft has only one radio compass.

(4) Where locators associated with ILS facilities serving opposite ends of a single runway are assigned a common frequency, provision shall be made to ensure that the facility not in operational use cannot radiate.

NDB identification

67. (1) Each NDB shall be individually identified by a two or three letter International Morse Code group transmitted at a rate corresponding to approximately seven words per minute.

(2) The complete identification shall be transmitted at least once every 30 or so seconds.

(3) Where the beacon is effected by on and off keying of the carrier the identification shall —

(*a*) be at approximately one minute intervals; or

(*b*) except that a shorter interval may be used at particular NDB stations where this is found to be operationally desirable; and

(*c*) except for those cases where the beacon identification is effected by on/off keying of the carrier, the identification signal shall be transmitted at least three times each 30 seconds, spaced equally within that time period.

(4). (1) For NDBs with an average radius of rated coverage of 92.7 km (50 NM) or less that are primarily approaches and holding aids in the vicinity of an aerodrome.

2. The identification shall —

(*a*) be transmitted at least three times each 30 seconds; and

(*b*) spaced equally within that time period.

(5) The frequency of the modulating tone used for identification shall be 1020 Hz plus or minus 50 Hz or 400 Hz plus or minus 25 Hz.

NDB characteristics of emissions

68. (1) Except as provided in subregulation (2), all NDBs shall radiate an uninterrupted carrier and be identified by on/off keying of an amplitude modulating tone (NON/A2A).

(2) NDBs other than those wholly or partly serving as holding, approach and landing aids, or those having an average radius of rated coverage of less than 92.7 km (50 NM), may be identified by on and off keying of the unmodulated carrier (NON/A1A) if they are in areas of high beacon density or where the required rated coverage is not practicable of achievement because of —

(*a*) radio interference from radio stations;

(*b*) high atmospheric noise; and

(*c*) local conditions.

(3) For each NDB identified by on/off keying of an audio modulating tone, the depth of modulation shall be maintained as near to 95 per cent as practicable.

(4) For each NDB identified by on/off keying of an audio modulating tone, the characteristics of emission during identification shall be such as to ensure satisfactory identification at the limit of its rated coverage.

(5) The carrier power of an NDB with NON/A2A emissions shall not fall when the identity signal is being radiated except that, in the case of an NDB having an average radius of rated coverage exceeding 92.7 km (50 NM), a fall of not more than 1.5 dB may be accepted.

(6) Unwanted audio frequency modulations shall total less than five per cent of the amplitude of the carrier.

(7) The bandwidth of emissions and the level of spurious emissions shall be kept at the lowest value that the state of technique and the nature of the service permit.

NDB siting of locators

69. (1) Where locators are used as a supplement to the ILS, they shall —

(*a*) be located at the sites of the outer and middle marker beacons; and

(*b*) where only one locator is used as a supplement to the ILS, preference shall be given to location at the site of the outer marker beacon.

(2) Where locators are employed as an aid to final approach in the absence of an ILS, equivalent locations to those applying when an ILS is installed shall be selected, taking into account the relevant obstacle clearance provisions of the PANS-OPS (ICAO Doc 8168 – Aircraft Operations).

(3) Where locators are installed at both the middle and outer marker positions, they shall be located, where practicable, on the same side of the extended centre line of the runway in order to provide a track between the locators which will be more nearly parallel to the centre line of the runway.

NDB monitoring

70. (1) For each NDB, suitable means shall be provided to enable detection of any of the following conditions at an appropriate location —

(*a*) a decrease in radiated carrier power of more than 50 per cent below that required for the rated coverage;

(*b*) failure to transmit the identification signal; and

(*c*) malfunctioning or failure of the means of monitoring itself.

(2) Where —

(*a*) an NDB is operated from a power source having a frequency which is close to airborne ADF equipment switching frequencies; and

(*b*) where the design of the NDB is such that the power supply frequency is likely to appear as a modulation product on the emission.

(3) Subject to subregulation (2) the means of monitoring shall be capable of detecting such power supply modulation on the carrier in excess of 5 per cent.

(4) During the hours of service of a locator, the means of monitoring shall provide for a continuous check on the functioning of the locator as prescribed in subregulation (1).

(5) During the hours of service of an NDB other than a locator, the means of monitoring shall provide for a continuous check on the functioning of the NDB as prescribed in subregulation (1).

(j) Specification for UHF distance measuring equipment (DME)

UHF distance measuring equipment

71. (1) The DME system shall provide for continuous and accurate indication in the cockpit of the slant range distance of an equipped aircraft from an equipped ground reference point.

(2) The system shall comprise two basic components, one fitted in the aircraft and the other installed on the ground.

(3) The aircraft component shall be referred to as the interrogator and the ground component as the transponder.

(4) In operation, interrogators shall interrogate transponders which shall, in turn, transmit to the interrogator replies synchronized with the interrogations, thus providing means for accurate measurement of distance.

(5) When a DME is associated with an ILS or VOR for the purpose of constituting a single facility, they shall —

(*a*) be operated on a standard frequency pairing in accordance with regulation 78 (3);

(*b*) be collocated within the limits prescribed for associated facilities in subregulation (5) and (6); and

(*c*) comply with the identification provisions of regulation 81 (4).

(6) Associated VOR and DME facilities shall be collocated in accordance with the following —

(*a*) for those facilities used in terminal areas for approach purposes or other procedures where the highest position fixing accuracy of system capability is required, the separation of the VOR and DME antennas does not exceed 80 m (260 ft); and

(*b*) for purposes other than those indicated in (*a*), the separation of the VOR and DME antennas does not exceed 600 m (2 000 ft).

Association of DME with ILS

72. The association of DME with ILS shall be in accordance with the guidelines set out in ICAO Annex 10, Volume 1, Attachment C, section 2.11.

UHF DME performance

73. The system shall provide a means of measurement of slant range distance from an aircraft to a selected transponder to the limit of coverage prescribed by the operational requirements for the selected transponder.

UHF DME coverage

74. (1) When associated with a VOR, DME/N coverage shall be at least that of the VOR to the extent practicable.

(2) When associated with an ILS, DME/N coverage shall be at least that of the respective ILS guidance coverage sectors.

UHF DME accuracy

75. (1) The accuracy standards specified in regulations 97 and 110 shall be met on a 95 per cent probability basis.

(2) The path following error (PFE) shall be comprised of those frequency components of the DME/P error at the output of the interrogator which lie below 1.5 rad/s.

(3) The control motion noise (CMN) shall be comprised of those frequency components of the DME/P error at the output of the interrogator which lie between 0.5 rad/s and 10 rad/s.

(4) Errors on the extended runway centre line shall not exceed the values given in Table B under Schedule 2.

UHF DME radio frequencies and polarization

76. The system shall operate with vertical polarization in the frequency band 960 MHz to 1 215 MHz and the interrogation and reply frequencies shall be assigned with 1 MHz spacing between channels.

UHF DME channelling

77. (1) DME operating channels shall be formed by pairing interrogation and reply frequencies and by pulse coding on the paired frequencies.

(2) DME operating channels shall be chosen from Table A under schedule 2 of 352 channels in which the channel numbers, frequencies, and pulse codes are assigned.

(3) Where a DME transponder is intended to operate in association with a single VHF navigation facility in the 108 MHz to 117.95 MHz frequency band, the DME operating channel shall be paired with the VHF channel as given in Table A order Schedule 2.

DME interrogation pulse repetition frequency

78. (1) The interrogator average pulse repetition frequency (PRF) shall not exceed 30 pairs of pulses per second, based on the assumption that at least 95 per cent of the time is occupied for tracking.

(2) If it is desired to decrease the time of search, the PRF may be increased during search but shall not exceed 150 pairs of pulses per second.

(3) After 15 000 pairs of pulses have been transmitted without acquiring indication of distance, the PRF shall not exceed 60 pairs of pulses per second thereafter, until a change in operating channel is made or a successful search is completed.

(4) Where, after a time period of 30 seconds, tracking has not been established, the pulse pair repetition frequency shall not exceed 30 pulse pairs per second thereafter.

UHF aircraft handling capacity of system

79. (1) The aircraft handling capacity of transponders in an area shall be adequate for the peak traffic of the area or 100 aircraft, whichever is the lesser.

(2) Where the peak traffic in an area exceeds 100 aircraft, the transponder shall be capable of handling that peak traffic.

UHF DME transponder identification

80. (1) A transponder shall transmit an identification signal in one of the following forms as required by regulation 82 —

(*a*) an "independent" identification consisting of coded (International Morse Code) identity pulses which can be used with all transponders; and

(*b*) an "associated" signal which can be used for transponders specifically associated with a VHF navigation facility which itself transmits an identification signal.

(2) Both systems of identification shall use signals, which shall consist of the transmission for an appropriate period of a series of paired pulses transmitted at a repetition rate of 1 350 pulse pairs per second, and shall temporarily replace all reply pulses that would normally occur at that time, except as in paragraph (*b*).

(3) The pulse referred to under subregulation (2), shall have similar characteristics to the other pulses of the reply signals in the following manner —

(*a*) reply pulses shall be transmitted between key down times; and

(*b*) if it is desired to preserve a constant duty cycle, an equalizing pair of pulses, having the same characteristics as the identification pulse pairs, shall be transmitted 100 microseconds plus or minus 10 microseconds after each identity pair.

(4) The characteristics of the "independent" identification signal shall be as follows —

(*a*) the identity signal shall consist of the transmission of the beacon code in the form of dots and dashes (International Morse Code) of identity pulses at least once every 40 seconds, at a rate of at least six words per minute;

(*b*) the identification code characteristic and letter rate for the DME transponder shall conform to the following to ensure that the maximum total key down time does not exceed six seconds per identification code group;

(*c*) the dots shall be a time duration of 0.1 second to 0.160 second. The dashes shall be typically three times the duration of the dots and the duration between dots and/or dashes shall be equal to that of one dot plus or minus 10 per cent; and

(*d*) the time duration between letters or numerals shall not be less than three dots and the total period for transmission of an identification code group shall not exceed 10 seconds.

(4) The characteristics of the "associated" signal shall be as follows —

(*a*) where associated with a VHF facility, the identification shall be transmitted in the form of dots and dashes (International Morse Code) as in subregulation (3) and shall be synchronized with the VHF facility identification code; and

(*b*) each 40-second interval shall be divided into four or more equal periods, with the transponder identification transmitted during one period only and the associated VHF facility identification, where these are provided, transmitted during the remaining periods.

UHF DME identification implementation

81. (1) The "independent" identification code shall be employed wherever a transponder is not specifically associated with a VHF navigational facility.

(2) Wherever a transponder is specifically associated with a VHF navigational facility, identification shall be provided by the "associated" code.

(3) Where voice communications are being radiated on an associated VHF navigational facility, an "associated" signal from the transponder shall not be suppressed.

(k) Characteristics of transponder and associated monitor

UHF DME transponder transmission component

82. (1) The transponder shall transmit on the reply frequency appropriate to the assigned DME channel.

(2) The radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

(3) The following shall apply to all radiated pulses —

(*a*) pulse rise time shall not exceed three microseconds;

(*b*) pulse duration shall be 3.5 microseconds plus or minus 0.5 microsecond;

(*c*) pulse decay time shall nominally be 2.5 microseconds but shall not exceed 3.5 microseconds;

(*d*) the instantaneous amplitude of the pulse shall not, at any instant between the point of the leading edge which is 95 per cent of maximum amplitude and the point of the trailing edge which is 95 per cent of the maximum amplitude, fall below a value which is 95 per cent of the maximum voltage amplitude of the pulse;

(*e*) the spectrum of the pulse modulated signal shall be such that during the pulse the EIRP contained in a 0.5 MHz band centred on frequencies 0.8 MHz above and 0.8 MHz;

(*f*) below the nominal channel frequency in each case shall not exceed 200 mW, and the EIRP contained in a 0.5 MHz band centred on frequencies 2 MHz above and 2 MHz;

(*g*) below the nominal channel frequency in each case shall not exceed 2 mW. The EIRP contained within any 0.5 MHz band shall decrease monotonically as the band centre frequency moves away from the nominal channel frequency;

(*h*) to ensure proper operation of the thresholding techniques, the instantaneous magnitude of any pulse turn-on transients which occur in time prior to the virtual origin shall be less than one per cent of the pulse peak amplitude; and

(*i*) initiation of the turn-on process shall not commence sooner than 1 microsecond prior to the virtual origin.

DME transponder pulse spacing

83. (1) The spacing of the constituent pulses of transmitted pulse pairs shall be as given in the table in regulation 96.

(2) The tolerance on the pulse spacing shall be plus or minus 0.25 microsecond.

(3) The tolerance on the DME/N pulse spacing shall be plus or minus 0.10 microsecond.

(4) The pulse spacings shall be measured between the half voltage points on the leading edges of the pulses.

DME transponder peak power output

84. (1) The peak EIRP shall not be less than that required to ensure a peak pulse power density of approximately minus 83 dBW/m^2 at the maximum specified range and level.

(2) The peak equivalent isotropically radiated power shall not be less than that required to ensure a peak pulse power density of minus 89 dBW/m^2 under all operational weather conditions at any point within coverage specified in regulation 75.

(3) The peak power of the constituent pulses of any pair of pulses shall not differ by more than 1 dB.

(4) The reply capability of the transmitter shall be such that the transponder shall be capable of continuous operation at a transmission rate of 2 700 plus or minus 90 pulse pairs per second (if 100 aircraft are to be served).

(5) The transmitter shall operate at a transmission rate, including randomly distributed pulse pairs and distance reply pulse pairs, of not less than 700 pulse pairs per second except during identity.

(6) The minimum transmission rate shall be as close as practicable to 700 pulse pairs per second and for DME/P, in no case shall it exceed 1 200 pulse pairs per second.

(7) (1) During intervals between transmission of individual pulses the spurious power received and measured in a receiver shall have the same characteristics as a transponder receiver.

(2) When tuned to any DME, interrogation or reply frequency, shall —

(*a*) be more than 50 dB below the peak pulse power received and measured in the same receiver tuned to the reply frequency in use during the transmission of the required pulses; and

(*b*) this provision refers to all spurious transmissions, including modulator and electrical interference.

(8) The spurious power level specified in subregulation (6) shall be more than 80 dB below the peak pulse power level.

(9) The spurious output of the DME transponder transmitter shall not exceed minus 40 dBm in any of KhZ receiver bandwidth at all frequencies from 10 to 1500 MHz, but band of frequencies from 960 to 1245 MHZ.

(10) The equivalent isotropically radiated power of any CW harmonic of the carrier frequency on any DME operating channel shall not exceed minus 10 dBm.

DME transponder receiver

85. (1) The receiver centre frequency shall be the interrogation frequency appropriate to the assigned DME operating channel.

(2) The centre frequency of the receiver shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

DME transponder sensitivity

86. (1) In the absence of all interrogation pulse pairs, with the exception of those necessary to perform the sensitivity measurement, interrogation pulse pairs with the correct spacing and nominal frequency shall trigger the transponder if the peak power density at the transponder antenna is at least —

(*a*) minus 103 dBW/m^2 for DME/N with coverage range greater than 56 km (30 NM); and

(*b*) minus 93 dBW/m^2 for DME/N with coverage range not greater than 56 km (30 NM).

(2) The minimum power densities specified in subregulation (1) shall cause the transponder to reply with an efficiency of at least —

(*a*) 70 per cent for DME/N;

(*b*) 70 per cent for DME/P IA mode; and

(*c*) 80 per cent for DME/P FA mode.

(3) The performance of the transponder shall be maintained when the power density of the interrogation signal at the transponder antenna has any value between the minimum specified in subregulation (1) up to a maximum of minus 22 dBW/m^2 when installed with ILS and minus 35 dBW/m^2 when installed for other applications.

(4) The transponder sensitivity level shall not vary by more than 1 dB for transponder loadings between 0 and 90 per cent of its maximum transmission rate.

(5) When the spacing of an interrogator pulse pair varies from the nominal value by up to plus or minus 1 microsecond, the receiver sensitivity shall not be reduced by more than 1 dB.

DME transponder load limiting

87. When transponder loading exceeds 90 per cent of the maximum transmission rate, the receiver sensitivity shall be automatically reduced in order to limit the transponder replies, so as to ensure that the maximum permissible transmission rate is not exceeded. (The available range of sensitivity reduction shall be at least 50 dB.)

DME transponder noise

88. When the receiver is interrogated at the power densities specified in subregulation 87 to produce a transmission rate equal to 90 per cent of the maximum, the noise generated pulse pairs shall not exceed 5 per cent of the maximum transmission rate.

DME transponder bandwidth

89. (1) The minimum permissible bandwidth of the receiver shall be such that the transponder sensitivity level shall not deteriorate by more than 3 dB when the total receiver drift is added to an incoming interrogation frequency drift of plus or minus 100 kHz.

(2) The receiver bandwidth shall be sufficient to allow compliance with Regulation 76 when the input signals are those specified in regulation 100 (3).

(3) Signals greater than 900 kHz removed from the desired channel nominal frequency and having power densities up to the values specified in subregulation 87 (3) DME/N shall not trigger the transponder. Signals arriving at the intermediate frequency shall be suppressed at least 80 dB. All other spurious response or signals within the 960 MHz to 1 215 MHz band and image frequencies shall be suppressed at least 75 dB.

90. (1) Within eight microseconds of the reception of a signal between 0 dB and 60 dB above minimum sensitivity level, the minimum sensitivity level of the transponder to a desired signal shall be within 3 dB of the value obtained in the absence of signals.

DME transponder recovery time

(2) The minimum sensitivity level reffered to in under subregulation (1) shall be met with echo suppression circuits, if any, rendered inoperative.

(3) The eight microseconds are to be measured between the half voltage points on the leading edges of the two signals, both of which conform in shape, with the specifications in regulation 100 (3).

91. Radiation from any part of the receiver or allied circuits shall meet the requirements stated in subregulation 85 (6).

DME transponder spurious radiations

92. (1) Carrier wave (CW) and echo suppression shall be adequate for the sites at which the transponders will be used.

DME transponder CW and echo suppression

93. Protection against interference outside the DME frequency band shall be adequate for the sites at which the transponders will be used.

DME transponder protection against interference

94. (1) The transponder shall include a decoding circuit such that the transponder can be triggered only by pairs of received pulses having pulse duration and pulse spacings appropriate to interrogator signals as described in regulations 100 (3) and 101 (1).

DME transponder decoding

(2) The decoding circuit performance shall not be affected by signals arriving before, between, or after, the constituent pulses of a pair of the correct spacing.

(3) An interrogation pulse pair with a spacing of plus or minus two microseconds, or more, from the nominal value and with any signal level up to the value specified in regulation 87 (3) shall not exceed the transmission rate, does not exceed the value obtained when interrogations are absent.

95. (1) Where a DME is associated only with a VHF facility, the time delay shall —

DME transponder time delay

(*a*) be the interval from the half voltage point on the leading edge of the second constituent pulse of the interrogation pair and the half voltage point on the leading edge of the second constituent pulse of the reply transmission; and

(*b*) this delay shall be consistent with the following table, when it is desired that aircraft interrogators are to indicate the distance from the transponder site.

		Pulse pair spacing (μs)		*Time delay (μs)*	
Channel suffix	*Operating mode*	*Interrogation*	*Reply*	*1st pulse timing*	*2nd pulse timing*
X	DME/N	12	12	50	50
	DME/P IA M	12	12	50	–
	DME/P FA M	18	12	56	–
Y	DME/N	36	30	56	50
	DME/P IA M	36	30	56	–
	DME/P FA M	42	30	62	–
W	DME/N	–	–	–	–
	DME/P IA M	24	24	50	–
	DME/P FA M	30	24	56	–
Z	DME/N	–	–	–	–
	DME/P IA M	21	15	56	–
	DME/P FA M	27	15	62	–

(2) Where a DME is associated with an angle facility, the time delay shall —

(*a*) be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pair; and

(*b*) the half voltage point on the leading edge of the first constituent pulse of the reply transmission.

(3) This delay shall —

(*a*) be 50 microseconds for mode X channels; and

(*b*) be 56 microseconds for mode Y channels, when it is desired that aircraft interrogators are to indicate distance from the transponder site.

(4) The transponder time delay shall —

(*a*) be capable of being set to an appropriate value between the nominal value of the time delay minus 15 microseconds; and

(*b*) the nominal value of the time delay, to permit aircraft interrogators to indicate zero distance at a specific point remote from the transponder site.

(5) The time delay shall —

(*a*) be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pair; and

(*b*) be the half voltage point on the leading edge of the first constituent pulse of the reply transmission.

DME transponder accuracy

96. (1) The transponder shall not contribute more than plus or minus one microsecond (150 m (500 ft)) to the overall system error.

(2) The contribution to the total system error due to the combination of the transponder errors, transponder location coordinate errors, propagation effects and random pulse interference effects shall be not greater than plus or minus 340 m (0.183 NM) plus 1.25 per cent of distance measure.

(3) The combination of the transponder errors, transponder location coordinate errors, propagation effects and random pulse interference effects shall not contribute more than plus or minus 185 m (0.1 NM) to the overall system error.

(4) A transponder associated with a landing aid shall not contribute more than plus or minus 0.5 microsecond (75 m (250 ft)) to the overall system error.

97. (1) The transponder reply efficiency shall be at least 70 per cent for DME/N at all values of transponder loading up to the loading corresponding to regulation 80 and at the minimum sensitivity level specified in regulation 87 (1) and (4).

DME transponder efficiency

(2) The transponder shall be rendered inoperative for a period normally not to exceed 60 microseconds after a valid interrogation decode has occurred and in extreme cases when the geographical site of the transponder is such as to produce undesirable reflection problems, the dead time may be increased but only by the minimum amount necessary to allow the suppression of echoes for DME/N.

98. (1) Means shall be provided at each transponder site for the automatic monitoring and control of the transponder in use.

DME transponder monitoring and control

(2) In the event that any of the conditions specified in subregulation (3) occur, the monitor shall cause the following action to take place —

(*a*) a suitable indication shall be given at a control point;

(*b*) the operating transponder shall be automatically switched off; and

(*c*) the standby transponder, if provided, shall be automatically placed in operation.

(3) The monitor shall cause the actions specified in subregulation (2) if —

(*a*) the transponder delay differs from the assigned value by one microsecond (150 m (500 ft)) or more; and

(*b*) in the case of a DME/N associated with a landing aid, the transponder delay differs from the assigned value by 0.5 microsecond (75 m (250 ft)) or more.

(4) The monitor shall cause the actions specified in subregulation (2) if the spacing between the first and second pulse of the transponder pulse pair differs from the nominal value specified in the table specified in regulation 96 by 1 microsecond or more.

(5) The monitor shall also cause a suitable indication to be given at a control point if any of the following conditions arise —

(*a*) a fall of 3 dB or more in transponder transmitted power output;

(*b*) a fall of 6 dB or more in the minimum transponder receiver sensitivity (provided that this is not due to the action of the receiver automatic gain reduction circuits);

(*c*) the spacing between the first and second pulse of the transponder reply pulse pair differs from the normal value specified in regulation 84 by 1 microsecond or more; and

(*d*) variation of the transponder receiver and transmitter frequencies beyond the control range of the reference circuits (if the operating frequencies are not directly crystal controlled).

(6) (1) Means shall be provided so that any of the conditions and malfunctioning enumerated in regulations 99 (3), 99 (4) and 99 (5) which are monitored shall persist for a certain period before the monitor takes action.

(2) This period shall be as low as practicable, but shall not exceed 10 seconds, consistent with the need for avoiding interruption, due to transient effects, of the service provided by the transponder.

(7) The transponder shall not be triggered more than 120 times per second for either monitoring or automatic frequency control purposes, or both.

(l) Technical characteristics of interrogator

DME interrogator transmitter

99. (1) The interrogator shall transmit on the interrogation frequency appropriate to the assigned DME channel as specified in regulation 78.

(2) The radio frequency of operation shall not vary more than plus or minus 100 kHz from the assigned value —

(*a*) Pulse rise time shall not exceed 3 microseconds;

(*b*) pulse duration shall be 3.5 microseconds plus or minus 0.5 microsecond;

(*c*) pulse decay time shall nominally be 2.5 microseconds, but shall not exceed 3.5 microseconds;

(*d*) the instantaneous amplitude of the pulse shall not, at any instant between the point of the leading edge which is 95 per cent of maximum amplitude and the point of the trailing edge which is 95 per cent of the maximum amplitude, fall below a value which is 95 per cent of the maximum voltage amplitude of the pulse;

(*e*) the spectrum of the pulse modulated signal shall be such that at least 90 per cent of the energy in each pulse shall be within 0.5 MHz in a band centred on the nominal channel frequency; and

(*f*) to ensure proper operation of the thresh holding techniques, the instantaneous magnitude of any pulse turn-on transients which occur in time prior to the virtual origin shall be less than one per cent of the pulse peak amplitude and the initiation of the turn-on process shall not commence sooner than 1 microsecond prior to the virtual origin.

DME interrogator pulse spacing

100. (1) The spacing of the constituent pulses of transmitted pulse pairs shall be as given in the table in regulation 96.

(2) The tolerance on the pulse spacing shall be plus or minus 0.5 microsecond.

(3) The tolerance on the pulse spacing shall be plus or minus 0.25 microsecond.

(4) The pulse spacing shall be measured between the half voltage points on the leading edges of the pulses.

DME interrogator pulse repetition frequency

101. The variation in time between successive pairs of interrogation pulses shall be sufficient to prevent false lock-on.

DME interrogator spurious radiation

102. (1) During intervals between transmission of individual pulses, the spurious pulse power received and measured in a receiver having the same characteristics of a DME transponder receiver, but tuned to any DME interrogation or reply frequency, shall —

(*a*) be more than 50 dB below the peak pulse power received; and

(*b*) be measured in the same receiver tuned to the interrogation frequency in use during the transmission of the required pulses.

(2) Subregulation 1 shall apply to all spurious pulse transmissions. The spurious CW power radiated from the interrogator on any DME interrogation or reply frequency shall not exceed 20 microwatts (minus 47 dBW).

(3) The spurious pulse power received and measured under the conditions stated in subregulation (1) shall be 80 dB below the required peak pulse power received.

DME interrogator time delay

103. (1) The time delay shall be consistent with the table in regulation 96.

(2) The time delay shall be the interval between the time of the half voltage point on the leading edge of the second constituent interrogation pulse and the time at which the distance circuits reach the condition corresponding to zero distance indication.

(3) The time delay shall be the interval between the time of the half voltage point on the leading edge of the first constituent interrogation pulse and the time at which the distance circuits reach the condition corresponding to zero distance indication.

104. (1) The receiver centre frequency shall be the transponder frequency appropriate to the assigned DME operating channel specified in regulation 78. DME interrogator receiver

105. The airborne equipment sensitivity shall be sufficient to acquire and provide distance information to the accuracy specified in regulation 110 and for the signal power density specified in regulation 85 (2). DME interrogator receiver sensitivity

(2) The performance of the interrogator shall be maintained when the power density of the transponder signal at the interrogator antenna is between the minimum values given in regulation 85 and a maximum of minus 18 dBW/m^2.

106. Where there is a ratio of desired to undesired co-channel DME signals of at least 8 dB at the input terminals of the airborne receiver, the interrogator shall display distance information and provide unambiguous identification from the stronger signal. DME interrogator bandwidth

107. (1) Where there is a ratio of desired to undesired co-channel DME signals of at least 8 dB at the input terminals of the airborne receiver, the interrogator shall display distance information and provide unambiguous identification from the stronger signal. DME interrogator interference rejection

(2) DME signals greater than 900 kHz removed from the desired channel nominal frequency and having amplitudes up to 42 dB above the threshold sensitivity shall not be used.

108. (1) The interrogator shall include a decoding circuit such that the receiver can be triggered only by pairs of received pulses having pulse duration and pulse spacings appropriate to transponder signals as described in regulation 84. DME interrogator decoding

(2) A reply pulse pair with a spacing of plus or minus two microseconds, or more, from the nominal value and with any signal level up to 42 dB above the receiver sensitivity shall be rejected.

109. The interrogator shall not contribute more than plus or minus 315 m (plus or minus 0.17 NM) or 0.25 per cent of indicated range, whichever is greater, to the overall system error. DME interrogator accuracy

(m) Specification for en-route VHF marker beacons (75 MHz)

110. The emissions of an en-route VHF marker beacon shall have a radio frequency of 75 MHz plus or minus 0.005 per cent. En-route VHF marker equipment

111. (1) Radio marker beacons shall radiate an uninterrupted carrier modulated to a depth of not less than 95 per cent or more than 100 per cent and the total harmonic content of the modulation shall not exceed 15 per cent. En-route VHF marker characteristics of emissions

(2) The frequency of the modulating tone shall be 3 000 Hz plus or minus 75 Hz.

(3) The radiation shall be horizontally polarized.

112. (1) If a coded identification is required at a radio marker beacon, the modulating tone shall be keyed so as to transmit dots or dashes or both in an appropriate sequence. The mode of keying shall be such as to provide a dot-and-dash duration together with spacing intervals corresponding to transmission at a rate equivalent to approximately six to ten words per minute. The carrier shall not be interrupted during identification. En-route VHF marker identification

En-route VHF marker coverage and radiation pattern

113. The most desirable radiation pattern would be one that —

(*a*) in the case of fan marker beacons, results in lamp operation only when the aircraft is within a rectangular parallelepiped, symmetrical about the vertical line through the marker beacon and with the major and minor axes adjusted in accordance with the flight path served; and

(*b*) in the case of a Z marker beacon, results in lamp operation only when the aircraft is within a cylinder, the axis of which is the vertical line through the marker beacons.

En-route VHF marker determination of coverage

114. The limits of coverage of marker beacons shall be determined on the basis of the field strength specified in regulation 44 (2).

En-route VHF marker radiation pattern

115. The radiation pattern of a marker beacon normally shall be such that the polar axis is vertical, and the field strength in the pattern is symmetrical about the polar axis in the plane or planes containing the flight paths for which the marker beacon is intended.

En-route VHF marker monitoring

116. For each marker beacon, suitable monitoring equipment shall be provided which will show at an appropriate location —

(*a*) a decrease in radiated carrier power below 50 per cent of normal;

(*b*) a decrease of modulation depth below 70 per cent; and

(*c*) a failure of keying.

(n) Requirements for the Global Navigation Satellite System (GNSS)

GNSS functions

117. The GNSS shall provide position and time data to the aircraft.

GNSS elements

118. The GNSS navigation service shall be provided using various combinations of the following elements installed on the ground, on satellites and/or on board the aircraft —

(*a*) Global Positioning System (GPS) that provides the Standard Positioning Service (SPS) as defined in regulations 123 to 136;

(*b*) Global Navigation Satellite System (GLONASS) that provides the Channel of Standard Accuracy (CSA) navigation signal as defined in regulations 137 to 148;

(*c*) aircraft-based augmentation system (ABAS) as defined in regulation 149;

(*d*) satellite-based augmentation system (SBAS) as defined in regulations 150 to 159;

(*e*) ground-based augmentation system (GBAS) as defined in regulation 160 to 171;

(*f*) ground-based regional augmentation system (GRAS) as defined in regulations 160 to 171; and

(*g*) aircraft GNSS receiver as defined in regulation 172.

GNSS space reference

119. The position information provided by the GNSS to the user shall be expressed in terms of the World Geodetic System — 1984 (WGS-84) geodetic reference datum.

GNSS time reference

120. The time data provided by the GNSS to the user shall be expressed in a time scale that takes the Universal Time Coordinated (UTC) as reference.

GNSS Signal-in-space performance

121. The combination of GNSS elements and a fault-free GNSS user receiver shall meet the signal-in-space requirements defined in table 3.7.2.4 – 1 under Schedule 1.

(o) GPS Standard Position Service (SPS) (L1)

122. (1) The GPS SPS position errors shall not exceed the following limits — GPS space and control segment accuracy

	Global average 95% of time	Worst site 95% of time
Horizontal position error	9 m (30 ft)	17 m (56 ft)
Vertical position error	15 m (49 ft)	37 m (121 ft)

(2) The GPS SPS time transfer errors shall not exceed 40 nanoseconds 95 per cent of the time.

123. The range domain error shall not exceed the following limits — GPS range domain accuracy

(*a*) range error of any satellite — 30 m (100 ft) with reliability specified in regulation 126;

(*b*) 95th percentile range rate error of any satellite — 0.006 m (0.02 ft) per second (global average);

(*c*) 95th percentile range acceleration error of any satellite — 0.002 m (0.006 ft) per second-squared (global average); and

(*d*) 95th percentile range error for any satellite over all time differences between time of data generation and time of use of data — 7.8 m (26 ft) (global average).

124. The GPS SPS availability shall be as follows — GPS availability

(*a*) ≥99 per cent horizontal service availability, average location (17 m 95 per cent threshold);

(*b*) ≥99 per cent vertical service availability, average location (37 m 95 per cent threshold);

(*c*) ≥90 per cent horizontal service availability, worst-case location (17 m 95 per cent threshold); and

(*d*) ≥90 per cent vertical service availability, worst-case location (37 m 95 per cent threshold).

125. (1) The GPS SPS reliability shall be within the following limits: GPS reliability

(*a*) reliability — at least 99.94 per cent (global average); and

(*b*) reliability — at least 99.79 per cent (worst single point average).

(2) The probability that the user range error (URE) of any satellite will exceed 4.42 times the upper bound on the user range accuracy (URA) broadcast by that satellite without an alert received at the user receiver antenna within 10 seconds, shall not exceed 1×10^{5} per hour.

126. The probability of losing GPS SPS signal-in-space (SIS) availability from a slot of the nominal 24-slot constellation due to unscheduled interruption shall not exceed 2×10^{4} per hour. GPS continuity

127. The GPS SPS shall cover the surface of the earth up to an altitude of 3 000 kilometres. GPS coverage

(p) Radio frequency (RF) characteristics

128. Each GPS satellite shall broadcast an SPS signal at the carrier frequency of 1 575.42 MHz (GPS L1) using code division multiple access (CDMA). GPS carrier frequency

GPS signal spectrum

129. The GPS SPS signal power shall be contained within a ±12 MHz band (1 563.42 – 1 587.42 MHz) centred on the L1 frequency.

GPS polarization

130. The transmitted RF signal shall be right-hand (clockwise) circularly polarized.

GPS signal power level

131. 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 five 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.

GPS modulation

132. The SPS L1 signal shall —

(*a*) be bipolar phase shift key (BPSK);

(*b*) modulated with a pseudo random noise (PRN) 1.023 MHz coarse/acquisition (C/A) code; and

(*c*) the C/A code sequence shall be repeated each millisecond.

(2) The transmitted PRN code sequence shall be the Modulo-2 addition of a 50 bits per second navigation message and the C/A code.

GPS time

133. GPS time shall be referenced to UTC (as maintained by the U.S. Naval Observatory).

GPS coordinate system

134. The GPS coordinate system shall be WGS-84.

GPS navigation information

135. The navigation data transmitted by the satellites shall include the necessary information to determine —

(*a*) satellite time of transmission;

(*b*) satellite position;

(*c*) satellite health;

(*d*) satellite clock correction;

(*e*) propagation delay effects;

(*f*) time transfer to UTC; and

(*g*) constellation status.

(q) GLONASS Channel of Standard Accuracy (CSA) (L1)

GLONASS space and control segment accuracy

136. (1) The GLONASS CSA position errors shall not exceed the following limits —

	Global average 95% of the time	Worst site 95% of the time
Horizontal position error	5 m (17 ft)	12 m (40 ft)
Vertical position error	9 m (29 ft)	25 m (97 ft)

(2) The GLONASS CSA time transfer errors shall not exceed 700 nanoseconds, 95 per cent of the time.

(3) The range domain error shall not exceed the following limits —

(*a*) range error of any satellite — 18 m (59.7 ft);

(*b*) range rate error of any satellite — 0.02 m (0.07 ft) per second;

(*c*) range acceleration error of any satellite — 0.007 m (0.023 ft) per second squared; and

(*c*) root-mean-square range error over all satellites — 6 m (19.9 ft).

137. The GLONASS CSA availability shall be as follows — GLONASS availability

(*a*) ≥99 per cent horizontal service availability, average location (12 m, 95 per cent threshold);

(*b*) ≥99 per cent vertical service availability, average location (25 m, 95 per cent threshold);

(*c*) ≥90 per cent horizontal service availability, worst-case location (12 m, 95 per cent threshold); and

(*d*) ≥90 per cent vertical service availability, worst-case location (25 m, 95 per cent threshold).

138. The GLONASS CSA reliability shall be within the following limits — GLONASS reliability

(*a*) frequency of a major service failure — not more than three per year for the constellation (global average); and

(*b*) reliability — at least 99.7 per cent (global average).

139. The GLONASS CSA shall cover the surface of the earth up to an altitude of 2 000 km. GLONASS coverage

140. Each GLONASS satellite shall broadcast CSA navigation signal at its own carrier frequency in the L1 (1.6 GHz) frequency band using frequency division multiple access (FDMA). GLONASS carrier frequency

141. GLONASS CSA signal power shall be contained within a ±5.75 MHz band centred on each GLONASS carrier frequency. GLONASS signal spectrum

142. The transmitted RF signal shall be right-hand circularly polarized. GLONASS polarization

143. 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. GLONASS signal power level

144. (1) Each GLONASS satellite shall transmit at its carrier frequency the navigation RF signal using a BPSK modulated binary train. GLONASS modulation

(2) The phase shift keying of the carrier shall be performed at π-radians with the maximum error ±0.2 radian and the pseudo-random code sequence shall be repeated each millisecond.

(3) The modulating navigation signal shall be generated by the Modulo-2 addition of the following three binary signals —

(*a*) ranging code transmitted at 511 kbits/s;

(*b*) navigation message transmitted at 50 bits/s; and

(*c*) 100 Hz auxiliary meander sequence.

145. GLONASS time shall be referenced to UTC (SU) (as maintained by the National Time Service of Russia). GLONASS time

146. The GLONASS coordinate system shall be PZ-90. GLONASS coordinate system

GLONASS navigation information

147. The navigation data transmitted by the satellite shall include the necessary information to determine —

(*a*) satellite time of transmission;
(*b*) satellite position;
(*c*) satellite health;
(*d*) satellite clock correction;
(*e*) time transfer to UTC; and
(*f*) constellation status.

(r) Aircraft-based augmentation system (ABAS)

ABAS performance

148. The ABAS function combined with one or more of the other GNSS elements and both a fault free GNSS receiver and fault-free aircraft system used for the ABAS function shall meet the requirements for accuracy, integrity, continuity and availability as stated in regulation 122.

(s) Satellite-band augmentation system (SBAS)

SBAS performance

149. (1) SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for system accuracy, integrity, continuity and availability for the intended operation as stated in regulation 122, throughout the corresponding service area in regulation 152 (6).

(2) SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for signal-in-space integrity as stated in regulation 122, throughout the SBAS coverage area.

SBAS functions

150. SBAS shall perform one or more of the following functions —

(*a*) ranging: provide an additional pseudo-range signal with an accuracy indicator from an SBAS satellite (regulation 152 and Schedule 3, section 3.5.7.2);
(*b*) GNSS satellite status: determine and transmit the GNSS satellite health status (Schedule 3, section 3.5.7.3);
(*c*) basic differential correction: provide GNSS satellite ephemeris and clock corrections (fast and long-term) to be applied to the pseudo-range measurements from satellites (Schedule 3, section 3.5.7.4); and
(*d*) precise differential correction: determine and transmit the ionospheric corrections (Schedule 3, section 3.5.7.5).

SBAS ranging

151. (1) Excluding atmospheric effects, the range error for the ranging signal from SBAS satellites shall not exceed 25 m (82 ft) (95 per cent).

(2) The probability that the range error exceeds 150 m (490 ft) in any hour shall not exceed 10^{5}.

(3) The probability of unscheduled outages of the ranging function from an SBAS satellite in any hour shall not exceed 10^{3}.

(4) The range rate error shall not exceed 2 m (6.6 ft) per second.

(5) The range acceleration error shall not exceed 0.019 m (0.06 ft) per second-squared.

(6) An SBAS service area for any approved type of operation shall be a declared area within the SBAS coverage area where SBAS meets the corresponding requirements of regulation 122.

SBAS carrier frequency

152. The carrier frequency shall be 1 575.42 MHz.

153. At least 95 per cent of the broadcast power shall be contained within a ±12 MHz band centred on the L1 frequency. The bandwidth of the signal transmitted by an SBAS satellite shall be at least 2.2 MHz. SBAS signal spectrum

154. (1) Each SBAS satellite placed in orbit before 1st 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 five 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. SBAS satellite signal power level

(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 Schedule 3, Table A-88, is at least –164.0 dBW;

(*b*) the minimum elevation angle used to determine GEO coverage shall not be less than five 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; and

(*d*) the elasticity of the broadcast signal shall be no worse than 2 dB for the angular range of ±9.1° from bore sight.

155. The broadcast signal shall be right-hand circularly polarized. SBAS polarization

156. The transmitted sequence shall — SBAS modulation

(*a*) the Modulo-2 addition of the navigation message be at a rate of 500 symbols per second and the 1 023 bit pseudo-random noise code; and

(*b*) it shall then be BPSK-modulated onto the carrier at a rate of 1.023 megachips per second.

157. The difference between SNT and GPS time shall not exceed 50 nanoseconds. SBAS network time (SNT)

158. The navigation data transmitted by the satellites shall include the necessary information to determine — SBAS navigation information

(*a*) SBAS satellite time of transmission;

(*b*) SBAS satellite position;

(*c*) corrected satellite time for all satellites;

(*d*) corrected satellite position for all satellites;

(*e*) ionospheric propagation delay effects;

(*f*) user position integrity;

(*g*) time transfer to UTC; and

(*h*) service level status.

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

159. GBAS combined with one or more of the other GNSS elements and a fault-free GNSS receiver shall meet the requirements for system accuracy, continuity, availability and integrity for the intended operation as stated in regulation 122 within the service volume for the service used to support the operation as defined in regulation 162. GBAS performance

GBAS functions

160. GBAS shall perform the following functions —

(*a*) provide locally relevant pseudo-range corrections;

(*b*) provide GBAS-related data;

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

(*d*) provide predicted ranging source availability data; and

(*e*) provide integrity monitoring for GNSS ranging sources.

GBAS service volume

161. The minimum GBAS guidance approach service volume shall be as follows, except where topographical features dictate, and operational requirements permit —

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

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

(*c*) vertically, within the lateral region, up to the greater of seven degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) to an upper bound of 3 000 m (10 000 ft) height above threshold (HAT) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure and the lower bound is half the lowest decision height supported or 3.7 m (12 ft), whichever is larger.

GBAS approach services supporting auto land and guided take-off

162. The minimum additional GBAS service volume to support approach operations that include automatic landing and rollout, including during guided take-off, shall be as follows, except where operational requirements permit —

(*a*) horizontally within a sector spanning the width of the runway beginning at the stop end of the runway and extending parallel with the runway centre line towards the LTP to join the minimum service volume as described in regulation 162; and

(*b*) vertically, between two horizontal surfaces one at 3.7 m (12 ft) and the other at 30 m (100 ft) above the runway centre line to join the minimum service volume as described in regulation 162.

GBAS positioning service

163. The minimum additional GBAS service volume to support approach operations that include automatic landing and rollout, including during guided take-off, shall be as follows, except where operational requirements permit —

(*a*) horizontally within a sector spanning the width of the runway beginning at the stop end of the runway and extending parallel with the runway centre line towards the LTP to join the minimum service volume as described in regulation 162; and

(*b*) vertically, between two horizontal surfaces one at 3.7 m (12 ft) and the other at 30 m (100 ft) above the runway centre line to join the minimum service volume as described in regulation 162.

164. The data broadcast radio frequencies used shall be selected from the radio frequencies in the band 108 to 117.975 MHz. GBAS carrier frequency

(2) The lowest assignable frequency shall be 108.025 MHz and the highest assignable frequency shall be 117.950 MHz and the separation between assignable frequencies (channel spacing) shall be 25 kHz.

165. A time division multiple access (TDMA) technique shall be used with a fixed frame structure. GBAS access technique

(2) The data broadcast shall be assigned one to eight slots.

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

167. (1) GBAS/H – A horizontally polarized signal shall be broadcast. GBAS data broadcast RF field strength and polarization

(2) The effective radiated power (ERP) shall —

(*a*) provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) ; and

(*b*) a maximum field strength of 0.350 volts per metre (–35 dBW/m^2) within the GBAS coverage volume.

(3) The field strength shall —

(*a*) be measured as an average over the period of the synchronization; and

(*b*) be such that the RF phase asset between the HPOL and any VPOL components, archieve the minimum signal power as defined in Schedule 3, section 3.6.8.2.2.3, and as such be archieved for HPOL users throughout the coverage volume.

(4) GBAS/E – An elliptically polarized signal shall be broadcast whenever practical.

(5). (1) Where an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in regulation 168 (2), and the effective radiated power (ERP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m^2) and a maximum field strength of 0.221 volts per metre (–39 dBW/m^2) within the GBAS coverage volume.

(6) The field strength shall —

(*a*) be measured as an average over the period of the synchronization and ambiguity resolution field of the burst; and

(*b*) be such that the RF phase offset between the HPOL and any VPOL components archieve the minimum signal power as defined in Schedule 3, section 3.6.8.2.2.3 ad as such be achieved for HPOL and VPOL users throughout the coverage volume.

168. The amount of power during transmission under all operating conditions when measured over a 25 kHz bandwidth centred on the ith adjacent channel shall not exceed the values shown in Schedule 1, table 3.7.3.5-1. GBAS power transmitted in adjacent channels

169. Unwanted emissions, including spurious and out-of-band emissions, shall be compliant with the levels shown in Schedule 1, table 3.7.3.5-2 and the total power in any VDB harmonic or discrete signal shall not be greater than –53 dBm. GBAS unwanted emissions

170. The navigation data transmitted by GBAS shall include the following information — GBAS navigation information

(*a*) pseudo-range corrections, reference time and integrity data;

(*b*) GBAS-related data;

(*c*) final approach segment data when supporting precision approach; and

(*d*) predicted ranging source availability data.

Aircraft GNSS receiver

171. The aircraft GNSS receiver shall process the signals of those GNSS elements that it intends to use as specified in Schedule 3, section 3.1 (for GPS), third schedule, section 3.2 (for GLONASS), Schedule 3, section 3.3 (for combined GPS and GLONASS), Schedule 3, section 3.5 (for SBAS) and Schedule 3, section 3.6 (for GBAS and GRAS).

GNSS resistance to interference

172. GNSS shall comply with performance requirements defined in regulation 122 and Schedule 3, section 3.7 in the presence of the interference environment defined in Schedule 3, section 3.7.

GNSS database

173. Aircraft GNSS equipment that uses a database shall provide a means to —

(*a*) update the electronic navigation database; and

(*b*) determine the Aeronautical Information Regulation and Control (AIRAC) effective dates of the aeronautical database.

(u) System characteristics of airborne ADF receiving systems

Accuracy of bearing indication

174. The bearing given by the ADF system shall not be in error by more than plus or minus five degrees with a radio signal from any direction having a field strength of 70 microvolts per metre or more radiated from an LF/MF NDB or locator operating within the tolerances permitted by these regulations and in the presence also of an unwanted signal from a direction 90 degrees from the wanted signal and shall be —

(*a*) on the same frequency and 15 dB weaker;

(*b*) plus or minus 2 kHz away and 4 dB weaker; and

(*c*) plus or minus 6 kHz or more away and 55 dB stronger.

PART IV — *Exemptions*

Application for exemption

175. A request for an exemption must be in writing and specify the time when the aviation service provider is expected by the Authority to fully comply.

Review and publication

176. (1) The Authority shall —

(*a*) review the application for exemption made under regulation 175 for accuracy and compliance; and

(*b*) if the application is satisfactory, the Authority shall publish a detailed summary of the application for comments, within a prescribed time, in either —

(i) the Government *Gazette*;

(ii) aeronautical information circular; and

(iii) a daily newspaper with national circulation in Botswana.

(2) Where application requirements have not been fully complied with, the Authority shall request the applicant in writing, to comply prior to publication or making a decision under subregulation (3).

(3) If the request is for emergency relief, the Authority shall publish the decision as soon as possible after processing the application.

Evaluation of the request

177. (1) Where the application requirements have been satisfied, the Authority shall conduct an evaluation of the request to include —

(*a*) determination of whether an exemption would be in the public interest;

(*b*) a determination, after a technical evaluation of whether the applicant's proposal would provide a level of safety equivalent to that established by these Regulations:

Provided that, where the Authority decides that a technical evaluation of the request would impose a significant burden on the Authority's technical resource, the Authority may deny the exemption on that basis;

(*c*) a determination of whether a grant of the exemption would contravene these Regulations; and

(*d*) a recommendation based on the preceding elements, of whether the request should be granted or denied, and of any conditions or limitations that should be part of the exemption.

PART V — *General provisions*

178. (1) Any person who performs any function prescribed by these Regulations directly or by contract may be tested for drug or alcohol usage. Drug and alcohol testing and reporting

(2) A person who —

(*a*) refuses to submit to a test to indicate the percentage by weight of alcohol in the blood; or

(*b*) refuses to submit to a test to indicate the presence of narcotic drugs, marijuana, or depressant or stimulant drugs or substances in the body, when requested by a law enforcement officer or the Authority, or refuses to furnish or to authorise the release of the test results requested by the Authority shall —

(i) be denied any licence, certificate, rating, qualification, or authorisation issued under these Regulations for a period of up to one year from the date of that refusal, or

(ii) have their licence, certificate, rating, qualification, or authorization issued under these Regulations suspended or revoked.

(3) Any person who is convicted for the violation of any local or national statute relating to the growing, processing, manufacture, sale, disposition, possession, transportation, or importation of narcotic drugs, marijuana, or depressant or stimulant drugs or substances, shall —

(*a*) be denied any license, certificate, rating, qualification, or authorisation issued under these Regulations for a period of up to one year after the date of conviction; or

(*b*) have their licence, certificate, rating, qualification, or authorisation issued under these Regulations suspended or revoked.

179. (1) Any person who knows of a violation of the Act, or any regulations, rules, or orders issued thereunder, shall report it to the Authority. Reports of violation

(2) The Authority may determine the nature and type of investigation or enforcement action that need to be taken.

180. Any person who fails to comply with any direction given to him by the Authority or by any authorised person under any provision of these Regulations shall be deemed for the purposes of these Regulations to have contravened that provision. Failure to comply with direction

181. (1) The Authority shall notify, in writing the fees to be charged in connection with the issue, renewal or variation of any certificate, test, inspection or investigation required by, or for the purpose of these Regulations, any orders, notices or proclamations made thereunder. Aeronautical fees

(2) Upon an application being made in connection with which any fee is chargeable in accordance with the provisions of subregulation (1), the applicant shall be required, before the application is accepted, to pay the fee so chargeable.

(3) If, after that payment has been made, the application is withdrawn by the applicant or otherwise ceases to have effect or is refused, the Authority shall not refund the payment made.

PART VI — *Offences and Penalties*

Contravention of Regulations

182. A person who contravenes any provision of these Regulations may have his certificate or exemption cancelled or suspended.

Penalties

183. (1) A person who contravenes any provision of these Regulations, orders, notices or proclamations made thereunder shall, upon conviction, be liable to a fine or imprisonment or both, and in the case of a continuing contravention, each day of the contravention shall constitute a separate offence.

(2) Any person who contravenes any provision of these Regulations shall be liable to a fine not exceeding P 100 000 or to imprisonment for a term not more than six months, or to both.

Appeal

184. A person aggrieved by the decision of the Authority under these Regulations may, within 14 days of such decision, appeal to the Tribunal established under section 79 of the Civil Aviation Act.

PART VII — *Savings and Transitions*

Savings and transition

185. (1) The Authority may require all facilities and equipment installed and operated before the coming into force of these Regulations be subjected to an assessment to determine the extent to which they comply with the provisions of these Regulations.

SCHEDULE 1

(Regulations 9, 10, 121, 168 and 169)

SPECIFICATIONS FOR RADIO NAVIGATION AIDS

Table 3.7.2.4-1 Signal-in-space performance requirements

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

NOTES.—

1. *The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in third schedule and guidance material is given in ICAO Annex 10, Vol. I Attachment C, 3.2.*

2. *The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. Further guidance on the alert limits is provided in ICAO Annex 10, Vol. I Attachment C, 3.3.6 to 3.3.10. These alert limits are:*

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV-II	40 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)

3. *The accuracy and time-to-alert requirements include the nominal performance of a fault-free receiver.*

4. *Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, and complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity (see ICAO Annex 10 Attachment C, 3.4.2). Continuity requirements for APV and Category I operations apply to the average risk (over time) of loss of service, normalized to a 15-second exposure time (see ICAO Annex 10, Vol. I Attachment C, 3.4.3).*

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV-II	40 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)

5. *A range of values is given for the availability requirements as these requirements are dependent upon the operational need which is based upon several factors including the frequency of operations, weather environments, the size and duration of the outages, availability of alternate navigation aids, radar coverage,*

traffic density and reversionary operational procedures. The lower values given are the minimum availabilities for which a system is considered to be practical but are not adequate to replace non-GNSS navigation aids. For en-route navigation, the higher values given are adequate for GNSS to be the only navigation aid provided in an area. For approach and departure, the higher values given are based upon the availability requirements at airports with a large amount of traffic assuming that operations to or from multiple runways are affected but reversionary operational procedures ensure the safety of the operation (see ICAO Annex 10, Vol. I Attachment C, 3.5).

6. *A range of values is specified for Category I precision approach. The 4.0 m (13 feet) requirement is based upon ILS specifications and represents a conservative derivation from these specifications (see ICAO Annex 10, Vol. I Attachment C, 3.2.7).*

7. *GNSS performance requirements for Category II and III precision approach operations are under review and will be included at a later date.*

8. *The terms APV-I and APV-II refer to two levels of GNSS approach and landing operations with vertical guidance (APV) and these terms are not necessarily intended to be used operationally.*

Table 3.7.3.5-1. GBAS broadcast power transmitted in adjacent channels

Channel	Relative power	Maximum power
1st adjacent	−40 dBc	12 dBm
2nd adjacent	−65 dBc	−13 dBm
4th adjacent	−74 dBc	−22 dBm
8th adjacent	−88.5 dBc	−36.5 dBm
16th adjacent	−101.5 dBc	−49.5 dBm
32nd adjacent	−105 dBc	−53 dBm
64th adjacent	−113 dBc	−61 dBm
76th adjacent and beyond	−115 dBc	−63 dBm

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

Table 3.7.3.5-2. GBAS broadcast unwanted emissions

Frequency	Relative unwanted emission level (Note 2)	Maximum unwanted emission level (Note 1)
9 kHz to 150 kHz	−93 dBc (Note 3)	−55 dBm/1 kHz (Note 3)
150 kHz to 30 MHz	−103 dBc (Note 3)	−55 dBm/10 kHz (Note 3)
30 MHz to 106.125 MHz	−115 dBc	−57 dBm/100 kHz
106.425 MHz	−113 dBc	−55 dBm/100 kHz
107.225 MHz	−105 dBc	−47 dBm/100 kHz
107.625 MHz	−101.5 dBc	−53.5 dBm/10 kHz
107.825 MHz	−88.5 dBc	−40.5 dBm/10 kHz
107.925 MHz	−74 dBc	−36 dBm/1 kHz
107.9625 MHz	−71 dBc	−33 dBm/1 kHz
107.975 MHz	−65 dBc	−27 dBm/1 kHz
118.000 MHz	−65 dBc	−27 dBm/1 kHz
118.0125 MHz	−71 dBc	−33 dBm/1 kHz
118.050 MHz	−74 dBc	−36 dBm/1 kHz
118.150 MHz	−88.5 dBc	−40.5 dBm/10 kHz
118.350 MHz	−101.5 dBc	−53.5 dBm/10 kHz
118.750 MHz	−105 dBc	−47 dBm/100 kHz
119.550 MHz	−113 dBc	−55 dBm/100 kHz
119.850 MHz to 1 GHz	−115 dBc	−57 dBm/100 kHz
1 GHz to 1.7 GHz	−115 dBc	−47 dBm/1 MHz

NOTES.—

1. *The maximum unwanted emission level (absolute power) applies if the authorized transmitter power exceeds 150 W.*
2. *The relative unwanted emission level is to be computed using the same bandwidth for desired and unwanted signals. This may require conversion of the measurement for unwanted signals done using the bandwidth indicated in the maximum unwanted emission level column of this table.*
3. *This value is driven by measurement limitations. Actual performance is expected to be better.*
4. *The relationship is linear between single adjacent points designated by the adjacent channels identified above*

SECOND SCHEDULE
(Regulations 75 and 77)

VHF LOCALIZER AND ASSOCIATED MONITOR SPECIFICATIONS

Table A. DME/MLS angle, DME/VOR and DME/ILS/MLS channelling and pairing

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
*1X	–	–	–	1 025	12	–	–	962	12
**1Y	–	–	–	1 025	36	–	–	1 088	30
*2X	–	–	–	1 026	12	–	–	963	12
**2Y	–	–	–	1 026	36	–	–	1 089	30
*3X	–	–	–	1 027	12	–	–	964	12
**3Y	–	–	–	1 027	36	–	–	1 090	30
*4X	–	–	–	1 028	12	–	–	965	12
**4Y	–	–	–	1 028	36	–	–	1 091	30
*5X	–	–	–	1 029	12	–	–	966	12
**5Y	–	–	–	1 029	36	–	–	1 092	30
*6X	–	–	–	1 030	12	–	–	967	12
**6Y	–	–	–	1 030	36	–	–	1 093	30
*7X	–	–	–	1 031	12	–	–	968	12
**7Y	–	–	–	1 031	36	–	–	1 094	30
*8X	–	–	–	1 032	12	–	–	969	12
**8Y	–	–	–	1 032	36	–	–	1 095	30
*9X	–	–	–	1 033	12	–	–	970	12
**9Y	–	–	–	1 033	36	–	–	1 096	30
*10X	–	–	–	1 034	12	–	–	971	12
**10Y	–	–	–	1 034	36	–	–	1 097	30
*11X	–	–	–	1 035	12	–	–	972	12
**11Y	–	–	–	1 035	36	–	–	1 098	30
*12X	–	–	–	1 036	12	–	–	973	12
**12Y	–	–	–	1 036	36	–	–	1 099	30
*13X	–	–	–	1 037	12	–	–	974	12
**13Y	–	–	–	1 037	36	–	–	1 100	30
*14X	–	–	–	1 038	12	–	–	975	12
**14Y	–	–	–	1 038	36	–	–	1 101	30
*15X	–	–	–	1 039	12	–	–	976	12
**15Y	–	–	–	1 039	36	–	–	1 102	30
*16X	–	–	–	1 040	12	–	–	977	12
**16Y	–	–	–	1 040	36	–	–	1 103	30

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
V17X	108.00	–	–	1 041	12	–	–	978	12
17Y	108.05	5 043.0	540	1 041	36	36	42	1 104	30
17Z	–	5 043.3	541	1 041	–	21	27	1 104	15
18X	108.10	5 031.0	500	1 042	12	12	18	979	12
18W	–	5 031.3	501	1 042	–	24	30	979	24
18Y	108.15	5 043.6	542	1 042	36	36	42	1 105	30
18Z	–	5 043.9	543	1 042	–	21	27	1 105	15
19X	108.20	–	–	1 043	12	–	–	980	12
19Y	108.25	5 044.2	544	1 043	36	36	42	1 106	30
19Z	–	5 044.5	545	1 043	–	21	27	1 106	15
20X	108.30	5 031.6	502	1 044	12	12	18	981	12
20W	–	5 031.9	503	1 044	–	24	30	981	24
20Y	108.35	5 044.8	546	1 044	36	36	42	1 107	30
20Z	–	5 045.1	547	1 044	–	21	27	1 107	15
21X	108.40	–	–	1 045	12	–	–	982	12
21Y	108.45	5 045.4	548	1 045	36	36	42	1 108	30
21Z	–	5 045.7	549	1 045	–	21	27	1 108	15
22X	108.50	5 032.2	504	1 046	12	12	18	983	12
22W	–	5 032.5	505	1 046	–	24	30	983	24
22Y	108.55	5 046.0	550	1 046	36	36	42	1 109	30
22Z	–	5 046.3	551	1 046	–	21	27	1 109	15
23X	108.60	–	–	1 047	12	–	–	984	12
23Y	108.65	5 046.6	552	1 047	36	36	42	1 110	30
23Z	–	5 046.9	553	1 047	–	21	27	1 110	15
24X	108.70	5 032.8	506	1 048	12	12	18	985	12
24W	–	5 033.1	507	1 048	–	24	30	985	24
24Y	108.75	5 047.2	554	1 048	36	36	42	1 111	30
24Z	–	5 047.5	555	1 048	–	21	27	1 111	15
25X	108.80	–	–	1 049	12	–	–	986	12
25Y	108.85	5 047.8	556	1 049	36	36	42	1 112	30
25Z	–	5 048.1	557	1 049	–	21	27	1 112	15
26X	108.90	5 033.4	508	1 050	12	12	18	987	12
26W	–	5 033.7	509	1 050	–	24	30	987	24
26Y	108.95	5 048.4	558	1 050	36	36	42	1 113	30
26Z	–	5 048.7	559	1 050	–	21	27	1 113	15
27X	109.00	–	–	1 051	12	–	–	988	12
27Y	109.05	5 049.0	560	1 051	36	36	42	1 114	30
27Z	–	5 049.3	561	1 051	–	21	27	1 114	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N μs	Initial approach μs	Final approach μs	Frequency MHz	Pulse codes μs
28X	109.10	5 034.0	510	1 052	12	12	18	989	12
28W	–	5 034.3	511	1 052	–	24	30	989	24
28Y	109.15	5 049.6	562	1 052	36	36	42	1 115	30
28Z	–	5 049.9	563	1 052	–	21	27	1 115	15
29X	109.20	–	–	1 053	12	–	–	990	12
29Y	109.25	5 050.2	564	1 053	36	36	42	1 116	30
29Z	–	5 050.5	565	1 053	–	21	27	1 116	15
30X	109.30	5 034.6	512	1 054	12	12	18	991	12
30W	–	5 034.9	513	1 054	–	24	30	991	24
30Y	109.35	5 050.8	566	1 054	36	36	42	1 117	30
30Z	–	5 051.1	567	1 054	–	21	27	1 117	15
31X	109.40	–	–	1 055	12	–	–	992	12
31Y	109.45	5 051.4	568	1 055	36	36	42	1 118	30
31Z	–	5 051.7	569	1 055	–	21	27	1 118	15
32X	109.50	5 035.2	514	1 056	12	12	18	993	12
32W	–	5 035.5	515	1 056	–	24	30	993	24
32Y	109.55	5 052.0	570	1 056	36	36	42	1 119	30
32Z	–	5 052.3	571	1 056	–	21	27	1 119	15
33X	109.60	–	–	1 057	12	–	–	994	12
33Y	109.65	5 052.6	572	1 057	36	36	42	1 120	30
33Z	–	5 052.9	573	1 057	–	21	27	1 120	15
34X	109.70	5 035.8	516	1 058	12	12	18	995	12
34W	–	5 036.1	517	1 058	–	24	30	995	24
34Y	109.75	5 053.2	574	1 058	36	36	42	1 121	30
34Z	–	5 053.5	575	1 058	–	21	27	1 121	15
35X	109.80	–	–	1 059	12	–	–	996	12
35Y	109.85	5 053.8	576	1 059	36	36	42	1 122	30
35Z	–	5 054.1	577	1 059	–	21	27	1 122	15
36X	109.90	5 036.4	518	1 060	12	12	18	997	12
36W	–	5 036.7	519	1 060	–	24	30	997	24
36Y	109.95	5 054.4	578	1 060	36	36	42	1 123	30
36Z	–	5 054.7	579	1 060	–	21	27	1 123	15
37X	110.00	–	–	1 061	12	–	–	998	12
37Y	110.05	5 055.0	580	1 061	36	36	42	1 124	30
37Z	–	5 055.3	581	1 061	–	21	27	1 124	15
38X	110.10	5 037.0	520	1 062	12	12	18	999	12
38W	–	5 037.3	521	1 062	–	24	30	999	24
38Y	110.15	5 055.6	582	1 062	36	36	42	1 125	30
38Z	–	5 055.9	583	1 062	–	21	27	1 125	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
39X	110.20	–	–	1 063	12	–	–	1 000	12
39Y	110.25	5 056.2	584	1 063	36	36	42	1 126	30
39Z	–	5 056.5	585	1 063	–	21	27	1 126	15
40X	110.30	5 037.6	522	1 064	12	12	18	1 001	12
40W	–	5 037.9	523	1 064	–	24	30	1 001	24
40Y	110.35	5 056.8	586	1 064	36	36	42	1 127	30
40Z	–	5 057.1	587	1 064	–	21	27	1 127	15
41X	110.40	–	–	1 065	12	–	–	1 002	12
41Y	110.45	5 057.4	588	1 065	36	36	42	1 128	30
41Z	–	5 057.7	589	1 065	–	21	27	1 128	15
42X	110.50	5 038.2	524	1 066	12	12	18	1 003	12
42W	–	5 038.5	525	1 066	–	24	30	1 003	24
42Y	110.55	5 058.0	590	1 066	36	36	42	1 129	30
42Z	–	5 058.3	591	1 066	–	21	27	1 129	15
43X	110.60	–	–	1 067	12	–	–	1 004	12
43Y	110.65	5 058.6	592	1 067	36	36	42	1 130	30
43Z	–	5 058.9	593	1 067	–	21	27	1 130	15
44X	110.70	5 038.8	526	1 068	12	12	18	1 005	12
44W	–	5 039.1	527	1 068	–	24	30	1 005	24
44Y	110.75	5 059.2	594	1 068	36	36	42	1 131	30
44Z	–	5 059.5	595	1 068	–	21	27	1 131	15
45X	110.80	–	–	1 069	12	–	–	1 006	12
45Y	110.85	5 059.8	596	1 069	36	36	42	1 132	30
45Z	–	5 060.1	597	1 069	–	21	27	1 132	15
46X	110.90	5 039.4	528	1 070	12	12	18	1 007	12
46W	–	5 039.7	529	1 070	–	24	30	1 007	24
46Y	110.95	5 060.4	598	1 070	36	36	42	1 133	30
46Z	–	5 060.7	599	1 070	–	21	27	1 133	15
47X	111.00	–	–	1 071	12	–	–	1 008	12
47Y	111.05	5 061.0	600	1 071	36	36	42	1 134	30
47Z	–	5 061.3	601	1 071	–	21	27	1 134	15
48X	111.10	5 040.0	530	1 072	12	12	18	1 009	12
48W	–	5 040.3	531	1 072	–	24	30	1 009	24
48Y	111.15	5 061.6	602	1 072	36	36	42	1 135	30
48Z	–	5 061.9	603	1 072	–	21	27	1 135	15
49X	111.20	–	–	1 073	12	–	–	1 010	12
49Y	111.25	5 062.2	604	1 073	36	36	42	1 136	30
49Z	–	5 062.5	605	1 073	–	21	27	1 136	15

Channel pairing				DME parameters					
				Interrogator				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
50X	111.30	5 040.6	532	1 074	12	12	18	1 011	12
50W	–	5 040.9	533	1 074	–	24	30	1 011	24
50Y	111.35	5 062.8	606	1 074	36	36	42	1 137	30
50Z	–	5 063.1	607	1 074	–	21	27	1 137	15
51X	111.40	–	–	1 075	12	–	–	1 012	12
51Y	111.45	5 063.4	608	1 075	36	36	42	1 138	30
51Z	–	5 063.7	609	1 075	–	21	27	1 138	15
52X	111.50	5 041.2	534	1 076	12	12	18	1 013	12
52W	–	5 041.5	535	1 076	–	24	30	1 013	24
52Y	111.55	5 064.0	610	1 076	36	36	42	1 139	30
52Z	–	5 064.3	611	1 076	–	21	27	1 139	15
53X	111.60	–	–	1 077	12	–	–	1 014	12
53Y	111.65	5 064.6	612	1 077	36	36	42	1 140	30
53Z	–	5 064.9	613	1 077	–	21	27	1 140	15
54X	111.70	5 041.8	536	1 078	12	12	18	1 015	12
54W	–	5 042.1	537	1 078	–	24	30	1 015	24
54Y	111.75	5 065.2	614	1 078	36	36	42	1 141	30
54Z	–	5 065.5	615	1 078	–	21	27	1 141	15
55X	111.80	–	–	1 079	12	–	–	1 016	12
55Y	111.85	5 065.8	616	1 079	36	36	42	1 142	30
55Z	–	5 066.1	617	1 079	–	21	27	1 142	15
56X	111.90	5 042.4	538	1 080	12	12	18	1 017	12
56W	–	5 042.7	539	1 080	–	24	30	1 017	24
56Y	111.95	5 066.4	618	1 080	36	36	42	1 143	30
56Z	–	5 066.7	619	1 080	–	21	27	1 143	15
57X	112.00	–	–	1 081	12	–	–	1 018	12
57Y	112.05	–	–	1 081	36	–	–	1 144	30
58X	112.10	–	–	1 082	12	–	–	1 019	12
58Y	112.15	–	–	1 082	36	–	–	1 145	30
59X	112.20	–	–	1 083	12	–	–	1 020	12
59Y	112.25	–	–	1 083	36	–	–	1 146	30
**60X	–	–	–	1 084	12	–	–	1 021	12
**60Y	–	–	–	1 084	36	–	–	1 147	30
**61X	–	–	–	1 085	12	–	–	1 022	12
**61Y	–	–	–	1 085	36	–	–	1 148	30
**62X	–	–	–	1 086	12	–	–	1 023	12
**62Y	–	–	–	1 086	36	–	–	1 149	30
**63X	–	–	–	1 087	12	–	–	1 024	12
**63Y	–	–	–	1 087	36	–	–	1 150	30

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
**64X	–	–	–	1 088	12	–	–	1 151	12
**64Y	–	–	–	1 088	36	–	–	1 025	30
**65X	–	–	–	1 089	12	–	–	1 152	12
**65Y	–	–	–	1 089	36	–	–	1 026	30
**66X	–	–	–	1 090	12	–	–	1 153	12
**66Y	–	–	–	1 090	36	–	–	1 027	30
**67X	–	–	–	1 091	12	–	–	1 154	12
**67Y	–	–	–	1 091	36	–	–	1 028	30
**68X	–	–	–	1 092	12	–	–	1 155	12
**68Y	–	–	–	1 092	36	–	–	1 029	30
**69X	–	–	–	1 093	12	–	–	1 156	12
**69Y	–	–	–	1 093	36	–	–	1 030	30
70X	112.30	–	–	1 094	12	–	–	1 157	12
**70Y	112.35	–	–	1 094	36	–	–	1 031	30
71X	112.40	–	–	1 095	12	–	–	1 158	12
**71Y	112.45	–	–	1 095	36	–	–	1 032	30
72X	112.50	–	–	1 096	12	–	–	1 159	12
**72Y	112.55	–	–	1 096	36	–	–	1 033	30
73X	112.60	–	–	1 097	12	–	–	1 160	12
**73Y	112.65	–	–	1 097	36	–	–	1 034	30
74X	112.70	–	–	1 098	12	–	–	1 161	12
**74Y	112.75	–	–	1 098	36	–	–	1 035	30
75X	112.80	–	–	1 099	12	–	–	1 162	12
**75Y	112.85	–	–	1 099	36	–	–	1 036	30
76X	112.90	–	–	1 100	12	–	–	1 163	12
**76Y	112.95	–	–	1 100	36	–	–	1 037	30
77X	113.00	–	–	1 101	12	–	–	1 164	12
**77Y	113.05	–	–	1 101	36	–	–	1 038	30
78X	113.10	–	–	1 102	12	–	–	1 165	12
**78Y	113.15	–	–	1 102	36	–	–	1 039	30
79X	113.20	–	–	1 103	12	–	–	1 166	12
**79Y	113.25	–	–	1 103	36	–	–	1 040	30
80X	113.30	–	–	1 104	12	–	–	1 167	12
80Y	113.35	5 067.0	620	1 104	36	36	42	1 041	30
80Z	–	5 067.3	621	1 104	–	21	27	1 041	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N μs	Initial approach μs	Final approach μs	Frequency MHz	Pulse codes μs
81X	113.40	–	–	1 105	12	–	–	1 168	12
81Y	113.45	5 067.6	622	1 105	36	36	42	1 042	30
81Z	–	5 067.9	623	1 105	–	21	27	1 042	15
82X	113.50	–	–	1 106	12	–	–	1 169	12
82Y	113.55	5 068.2	624	1 106	36	36	42	1 043	30
82Z	–	5 068.5	625	1 106	–	21	27	1 043	15
83X	113.60	–	–	1 107	12	–	–	1 170	12
83Y	113.65	5 068.8	626	1 107	36	36	42	1 044	30
83Z	–	5 069.1	627	1 107	–	21	27	1 044	15
84X	113.70	–	–	1 108	12	–	–	1 171	12
84Y	113.75	5 069.4	628	1 108	36	36	42	1 045	30
84Z	–	5 069.7	629	1 108	–	21	27	1 045	15
85X	113.80	–	–	1 109	12	–	–	1 172	12
85Y	113.85	5 070.0	630	1 109	36	36	42	1 046	30
85Z	–	5 070.3	631	1 109	–	21	27	1 046	15
86X	113.90	–	–	1 110	12	–	–	1 173	12
86Y	113.95	5 070.6	632	1 110	36	36	42	1 047	30
86Z	–	5 070.9	633	1 110	–	21	27	1 047	15
87X	114.00	–	–	1 111	12	–	–	1 174	12
87Y	114.05	5 071.2	634	1 111	36	36	42	1 048	30
87Z	–	5 071.5	635	1 111	–	21	27	1 048	15
88X	114.10	–	–	1 112	12	–	–	1 175	12
88Y	114.15	5 071.8	636	1 112	36	36	42	1 049	30
88Z	–	5 072.1	637	1 112	–	21	27	1 049	15
89X	114.20	–	–	1 113	12	–	–	1 176	12
89Y	114.25	5 072.4	638	1 113	36	36	42	1 050	30
89Z	–	5 072.7	639	1 113	–	21	27	1 050	15
90X	114.30	–	–	1 114	12	–	–	1 177	12
90Y	114.35	5 073.0	640	1 114	36	36	42	1 051	30
90Z	–	5 073.3	641	1 114	–	21	27	1 051	15
91X	114.40	–	–	1 115	12	–	–	1 178	12
91Y	114.45	5 073.6	642	1 115	36	36	42	1 052	30
91Z	–	5 073.9	643	1 115	–	21	27	1 052	15
92X	114.50	–	–	1 116	12	–	–	1 179	12
92Y	114.55	5 074.2	644	1 116	36	36	42	1 053	30
92Z	–	5 074.5	645	1 116	–	21	27	1 053	15
93X	114.60	–	–	1 117	12	–	–	1 180	12
93Y	114.65	5 074.8	646	1 117	36	36	42	1 054	30
93Z	–	5 075.1	647	1 117	–	21	27	1 054	15

Channel pairing				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
94X	114.70	–	–	1 118	12	–	–	1 181	12
94Y	114.75	5 075.4	648	1 118	36	36	42	1 055	30
94Z	–	5 075.7	649	1 118	–	21	27	1 055	15
95X	114.80	–	–	1 119	12	–	–	1 182	12
95Y	114.85	5 076.0	650	1 119	36	36	42	1 056	30
95Z	–	5 076.3	651	1 119	–	21	27	1 056	15
96X	114.90	–	–	1 120	12	–	–	1 183	12
96Y	114.95	5 076.6	652	1 120	36	36	42	1 057	30
96Z	–	5 076.9	653	1 120	–	21	27	1 057	15
97X	115.00	–	–	1 121	12	–	–	1 184	12
97Y	115.05	5 077.2	654	1 121	36	36	42	1 058	30
97Z	–	5 077.5	655	1 121	–	21	27	1 058	15
98X	115.10	–	–	1 122	12	–	–	1 185	12
98Y	115.15	5 077.8	656	1 122	36	36	42	1 059	30
98Z	–	5 078.1	657	1 122	–	21	27	1 059	15
99X	115.20	–	–	1 123	12	–	–	1 186	12
99Y	115.25	5 078.4	658	1 123	36	36	42	1 060	30
99Z	–	5 078.7	659	1 123	–	21	27	1 060	15
100X	115.30	–	–	1 124	12	–	–	1 187	12
100Y	115.35	5 079.0	660	1 124	36	36	42	1 061	30
100Z	–	5 079.3	661	1 124	–	21	27	1 061	15
101X	115.40	–	–	1 125	12	–	–	1 188	12
101Y	115.45	5 079.6	662	1 125	36	36	42	1 062	30
101Z	–	5 079.9	663	1 125	–	21	27	1 062	15
102X	115.50	–	–	1 126	12	–	–	1 189	12
102Y	115.55	5 080.2	664	1 126	36	36	42	1 063	30
102Z	–	5 080.5	665	1 126	–	21	27	1 063	15
103X	115.60	–	–	1 127	12	–	–	1 190	12
103Y	115.65	5 080.8	666	1 127	36	36	42	1 064	30
103Z	–	5 081.1	667	1 127	–	21	27	1 064	15
104X	115.70	–	–	1 128	12	–	–	1 191	12
104Y	115.75	5 081.4	668	1 128	36	36	42	1 065	30
104Z	–	5 081.7	669	1 128	–	21	27	1 065	15
105X	115.80	–	–	1 129	12	–	–	1 192	12
105Y	115.85	5 082.0	670	1 129	36	36	42	1 066	30
105Z	–	5 082.3	671	1 129	–	21	27	1 066	15
106X	115.90	–	–	1 130	12	–	–	1 193	12
106Y	115.95	5 082.6	672	1 130	36	36	42	1 067	30
106Z	–	5 082.9	673	1 130	–	21	27	1 067	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N μs	Initial approach μs	Final approach μs	Frequency MHz	Pulse codes μs
107X	116.00	–	–	1 131	12	–	–	1 194	12
107Y	116.05	5 083.2	674	1 131	36	36	42	1 068	30
107Z	–	5 083.5	675	1 131	–	21	27	1 068	15
108X	116.10	–	–	1 132	12	–	–	1 195	12
108Y	116.15	5 083.8	676	1 132	36	36	42	1 069	30
108Z	–	5 084.1	677	1 132	–	21	27	1 069	15
109X	116.20	–	–	1 133	12	–	–	1 196	12
109Y	116.25	5 084.4	678	1 133	36	36	42	1 070	30
109Z	–	5 084.7	679	1 133	–	21	27	1 070	15
110X	116.30	–	–	1 134	12	–	–	1 197	12
110Y	116.35	5 085.0	680	1 134	36	36	42	1 071	30
110Z	–	5 085.3	681	1 134	–	21	27	1 071	15
111X	116.40	–	–	1 135	12	–	–	1 198	12
111Y	116.45	5 085.6	682	1 135	36	36	42	1 072	30
111Z	–	5 085.9	683	1 135	–	21	27	1 072	15
112X	116.50	–	–	1 136	12	–	–	1 199	12
112Y	116.55	5 086.2	684	1 136	36	36	42	1 073	30
112Z	–	5 086.5	685	1 136	–	21	27	1 073	15
113X	116.60	–	–	1 137	12	–	–	1 200	12
113Y	116.65	5 086.8	686	1 137	36	36	42	1 074	30
113Z	–	5 087.1	687	1 137	–	21	27	1 074	15
114X	116.70	–	–	1 138	12	–	–	1 201	12
114Y	116.75	5 087.4	688	1 138	36	36	42	1 075	30
114Z	–	5 087.7	689	1 138	–	21	27	1 075	15
115X	116.80	–	–	1 139	12	–	–	1 202	12
115Y	116.85	5 088.0	690	1 139	36	36	42	1 076	30
115Z	–	5 088.3	691	1 139	–	21	27	1 076	15
116X	116.90	–	–	1 140	12	–	–	1 203	12
116Y	116.95	5 088.6	692	1 140	36	36	42	1 077	30
116Z	–	5 088.9	693	1 140	–	21	27	1 077	15
117X	117.00	–	–	1 141	12	–	–	1 204	12
117Y	117.05	5 089.2	694	1 141	36	36	42	1 078	30
117Z	–	5 089.5	695	1 141	–	21	27	1 078	15
118X	117.10	–	–	1 142	12	–	–	1 205	12
118Y	117.15	5 089.8	696	1 142	36	36	42	1 079	30
118Z	–	5 090.1	697	1 142	–	21	27	1 079	15
119X	117.20	–	–	1 143	12	–	–	1 206	12
119Y	117.25	5 090.4	698	1 143	36	36	42	1 080	30
119Z	–	5 090.7	699	1 143	–	21	27	1 080	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
120X	117.30	–	–	1 144	12	–	–	1 207	12
120Y	117.35	–	–	1 144	36	–	–	1 081	30
121X	117.40	–	–	1 145	12	–	–	1 208	12
121Y	117.45	–	–	1 145	36	–	–	1 082	30
122X	117.50	–	–	1 146	12	–	–	1 209	12
122Y	117.55	–	–	1 146	36	–	–	1 083	30
123X	117.60	–	–	1 147	12	–	–	1 210	12
123Y	117.65	–	–	1 147	36	–	–	1 084	30
124X	117.70	–	–	1 148	12	–	–	1 211	12
**124Y	117.75	–	–	1 148	36	–	–	1 085	30
125X	117.80	–	–	1 149	12	–	–	1 212	12
**125Y	117.85	–	–	1 149	36	–	–	1 086	30
126X	117.90	–	–	1 150	12	–	–	1 213	12
**126Y	117.95	–	–	1 150	36	–	–	1 087	30

* These channels are reserved exclusively for national allotments.
** These channels may be used for national allotment on a secondary basis.
The primary reason for reserving these channels is to provide protection for the secondary surveillance radar (SSR) system.
108.0 MHz is not scheduled for assignment to ILS service. The associated DME operating channel No. 17X may be assigned for emergency use. The reply frequency of channel No. 17X (i.e. 978 MHz) is also utilized for the operation of the universal access transceiver (UAT). Standards and Recommended Practices for UAT are found in Annex 10, Volume III, Part I, Chapter 12.

Table B. Allowable DME/P errors

Location	Standard	Mode	PFE	CMN
37 km (20 NM) to 9.3 km (5 NM) from MLS approach reference datum	1 and 2	IA	±250 m (±820 ft) reducing linearly to ±85 m (±279 ft)	±68 m (±223 ft) reducing linearly to ±34 m (±111 ft)
9.3 km (5 NM) to MLS approach reference datum	1	FA	±85 m (±279 ft) reducing linearly to ±30 m (±100 ft)	±18 m (±60 ft)
	2	FA	±85 m (±279 ft) reducing linearly to ±12 m (±40 ft)	±12 m (±40 ft)
	see Note	IA	±100 m (±328 ft)	±68 m (±223 ft)
At MLS approach reference datum and through runway coverage	1	FA	±30 m (±100 ft)	±18 m (±60 ft)
	2	FA	±12 m (±40 ft)	±12 m (±40 ft)
Throughout back azimuth coverage volume	1 and 2	FA	±100 m (±328 ft)	±68 m (±223 ft)
	see Note	IA	±100 m (±328 ft)	±68 m (±223 ft)

Note.— At distances from 9.3 km (5 NM) to the MLS approach reference datum and throughout the back azimuth coverage, the IA mode may be used when the FA mode is not operative.

THIRD SCHEDULE
(regulations 33, 101, 150, 154, 167, 171 and 172)

TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

1. Definitions

GBAS/E. A ground-based augmentation system transmitting an elliptically-polarized VHF data broadcast.

GBAS/H. A ground-based augmentation system transmitting a horizontally-polarized VHF data broadcast.

Receiver. A subsystem that receives GNSS signals and includes one or more sensors.

Reserved (bits/words/fields). Bits/words/fields that are not allocated, but which are reserved for a particular GNSS application.

Spare (bits/words/fields). Bits/words/fields that are not allocated or reserved, and which are available for future allocation.

Note All spare bits are set to zero.

2. General

Note: The following technical specifications supplement the provisions of 117 - 121

3. GNSS Elements

3.1 Global Positioning System (GPS) Standard Positioning Service (SPS) (L1)

3.1.1 Non-Aircraft Elements

3.1.1.1 Radio Frequency (RF) Characteristics

3.1.1.1.1 Carrier phase noise. The carrier phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

3.1.1.1.2 Spurious emissions. In-band spurious emissions shall be at least 40 dB below the unmodulated L1 carrier over the allocated channel bandwidth.

Note.— The loss in signal power is the difference between the broadcast power in a2.046 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and a 2.046 MHz bandwidth.

.4 Coarse/acquisition (C/A) code generation and timing. Each C/A code pattern $G_i(t)$ shall be formed by the Modulo-2 sum of two 1 023-bit linear patterns, G1 and $G2_i$. The $G2_i$ sequence shall be formed by effectively delaying the G2 sequence by an integer number of chips to produce one of 36 unique $G_i(t)$ patterns defined in Table A-1. The G1 and G2 sequences shall be generated by 10-stage shift registers having the following polynomials as referred to in the shift register input:

a) G1: $X^{10} + X^3 + 1$; and

b) G2: $X^{10} + X^9 + X^8 + X^6 + X^3 + X^2 + 1$.

The initialization vector for the G1 and G2 sequences shall be "1111111111". The code phase assignments shall be as shown in Table A-1. The G1 and G2 registers shall be clocked at a 1.023 MHz rate. Timing relationships related to the C/A code shall be as shown in Figure B-1.*

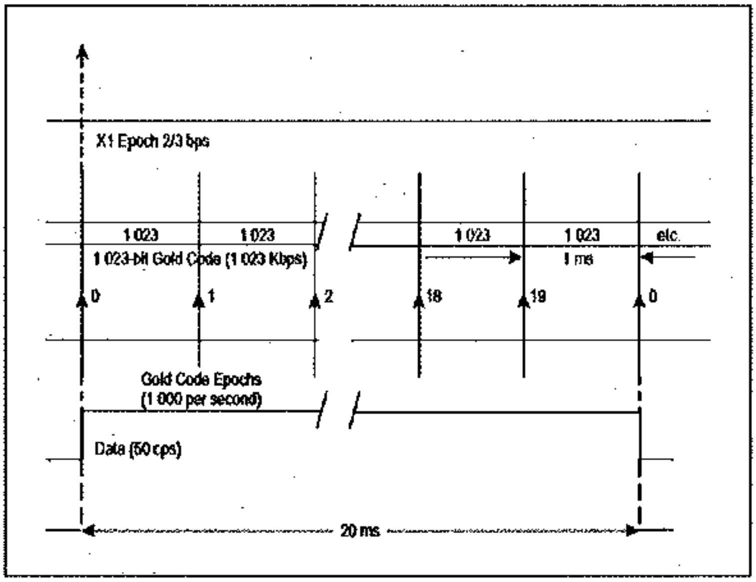

Figure B – 1 C/A code timing relationships

Data structure. The navigation message shall be formatted as shown in Figure B-2. Each page, as shown in Figure B-6, shall utilize a basic format of a 1 500-bit-long frame with up to 5 subframes, each of 300 bits in length. All words shall be transmitted most significant bit (MSB) first.

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

Figure B – 2 Frame structure

3.1.1.2.1 Subframe structure. Each subframe and/or page of a subframe shall start with a telemetry (TLM) word followed by a handover word (HOW). The HOW shall be followed by 8 data words. Each word in each frame shall contain 6 parity bits. The TLM word and HOW formats shall be as shown in Figures B-3 and B-4, respectively.

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

Figure B-3 TLM word format

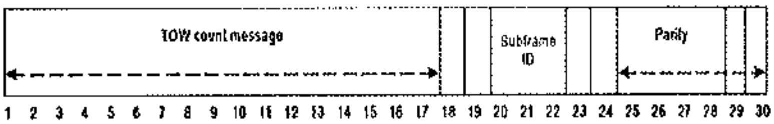

Figure B-4 HOW format

3.1.1.2.2 End/start of week. At the end/start of week:

a) the cyclic paging of subframes 1 through 5 shall restart with subframe 1 regardless of which subframe was last transmitted prior to the end/start of week;

and

b) the cycling of 25 pages of subframes 4 and 5 shall restart with page 1 of each of the subframes, regardless of which page was transmitted prior to the end/start of week. All upload and page cutovers shall occur on frame boundaries (i.e. Modulo 30 seconds relative to the end/start of week).

Note.— New data in subframes 4 and 5 may start to be transmitted with any of the 25 pages of these subframes.

3.1.1.2.3 Data parity. Words 1 through 10 of subframes 1 through 5 shall each contain 6 parity bits as their least significant bits (LSBs). In addition, two non-information bearing bits shall be provided as bits 23 and 24 of words 2 and 10 for parity computation purposes.

3.1.1.2.4 Telemetry (TLM) word. Each TLM word shall be 30 bits long, occur every 6 seconds in the data frame and be the first word in each subframe. The TLM format shall be as shown in Figure B-3. Each TLM word shall begin with a preamble, followed by 16 reserved bits and 6 parity bits.

3.1.1.2.5 Handover word (HOW). The HOW shall be 30 bits long and shall be the second word in each subframe/page, immediately following the TLM word. A HOW shall occur every 6 seconds in the data frame. The HOW format and content shall be as shown in Figure B-4. The full time-of-week (TOW) count shall consist of the 19 LSBs of the 29-bit Z-count (3.1.1.2.6). The HOW shall begin with the 17 MSBs of the TOW count. These 17 bits shall correspond to the TOW count at the 1.5-second epoch that occurs at the start (leading edge) of the next following subframe.

3.1.1.2.5.1 Bit 18. On satellites designed by configuration code 001, bit 18 shall be an "alert" flag. When this flag is raised (bit 18 is a "1"), it shall indicate to the user that the satellite user range accuracy (URA) may be worse than indicated in subframe 1 and that use of the satellite is at the user's risk.

Table A-1. Code phase assignments

Satellite ID number	GPS PRN signal	G2 delay (chips)	First 10 chips octal*
1	1	5	1440
2	2	6	1620
3	3	7	1710
4	4	8	1744
5	5	17	1133
6	6	18	1455
7	7	139	1131
8	8	140	1454
9	9	141	1626
10	10	251	1504
11	11	252	1642
12	12	254	1750
13	13	255	1764
14	14	256	1772
15	15	257	1775
16	16	258	1776
17	17	469	1156
18	18	470	1467
19	19	471	1633
20	20	472	1715
21	21	473	1746
22	22	474	1763
23	23	509	1063
24	24	512	1706
25	25	513	1743
26	26	514	1761
27	27	515	1770
28	28	516	1774
29	29	859	1127
30	30	860	1453
31	31	861	1625
32	32	862	1712
***	33	863	1745
***	34**	950	1713
***	35	947	1134
***	36	948	1456
***	37**	950	1713

* In the octal notation for the first 10 chips of the C/A code as shown in this column, the first digit represents a "1" for the first chip and the last three digits are the conventional octal representation of the remaining 9 chips (e.g. the first 10 chips of the C/A code for pseudo-random noise (PRN) signal assembly 1 are: 1100100000).

** C/A codes 34 and 37 are common.

*** PRN signal assemblies 33 through 37 are reserved for other uses (e.g. ground transmitters).

Bit 19. Bit 19 shall be reserved.

3.1.1.2.5.2 Bits 20, 21 and 22. Bits 20, 21 and 22 of the HOW shall provide the identification (ID) of the subframe in which that particular HOW is the second word. The ID code shall be as defined below:

ID	Code
1	001
2	010
3	011
4	100
5	101

3.1.1.2.6 Satellite Z-count. Each satellite shall internally derive a 1.5-second epoch that shall contain a convenient unit for precisely counting and communicating time. Time stated in this manner shall be referred to as a Z-count. The Z-count shall be provided to the user as a 29-bit binary number consisting of two parts as follows.

3.1.1.2.6.1 Time-of-week (TOW) count. The binary number represented by the 19 LSBs of the Z-count shall be referred to as the TOW count and is defined as being equal to the number of 1.5-second epochs that have occurred since the transition from the previous week. The count shall be short-cycled such that the range of the TOW count is from 0 to 403 199 1.5-second epochs (equalling one week) and shall be reset to zero at the end of each week. The TOW count's zero state shall be the 1.5-second epoch that is coincident with the start of the present week. A truncated version of the TOW count, consisting of its 17 MSBs, shall be contained in the HOW of the L1 downlink data stream. The relationship between the actual TOW count and its truncated HOW version shall be as indicated in Figure B-5.

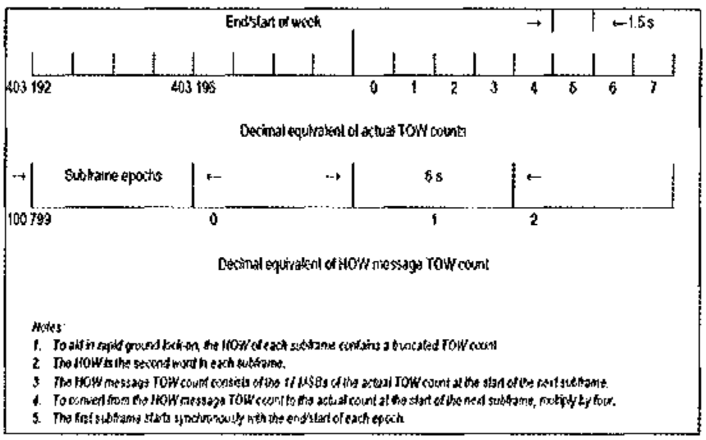

Figure B-5 Time line relationship of HOW

Note.— The above-mentioned epoch occurs at (approximately) midnight Saturday night/Sunday morning, where midnight is defined as 0000 hours on the UTC scale which is nominally referenced to the Greenwich Meridian.

3.1.1.2.6.2 Week count. The 10 MSBs of the Z-count shall be a binary representation of the sequential number assigned to the present GPS week (Modulo 1024). The range of this count shall be from 0 to 1 023. Its zero state shall be that week which starts with the 1.5-second epoch occurring at (approximately) the UTC zero time point (3.1.4). At the expiration of GPS week number 1 023, the GPS week number shall roll over to zero. The previous 1 024 weeks in conversions from GPS time to a calendar date shall be accounted for by the user.

3.1.1.3 Data Content

3.1.1.3.1 Subframe 1 — satellite clock and health data. The content of words 3 through 10 of subframe 1 shall contain the clock parameters and other data as indicated in Table A-2. The parameters in a data set shall be valid during the interval of time in which they are transmitted and shall remain valid for an additional period of time after transmission of the next data set has started.

3.1.1.3.1.1 Week number. The 10 MSBs of word 3 shall contain the 10 MSBs of the 29-bit Z-count and shall represent the number of the current GPS week at the start of the data set transmission interval with all zeros indicating week "zero." The GPS week number shall increment at each end/start of week epoch.

3.1.1.3.1.2 User range accuracy (URA). Bits 13 through 16 of word 3 shall provide the predicted satellite URA as shown in Table A-3.

Note 1.— The URA does not include error estimates due to inaccuracies of the single-frequency ionospheric delay model.

Note 2.— The URA is a statistical indicator of the contribution of the apparent clock and ephemeris prediction accuracies to the ranging accuracies obtainable with a specific satellite based on historical data.

Table A-2. Subframe 1 parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
Week number	10	1		weeks
Satellite accuracy	4			
Satellite health	6	1		discretes
T_{GD}	8*	2^{-31}		seconds
IODC	10			
t_{oc}	16	2^{4}	604 784	seconds
a_{f2}	8*	2^{-55}		seconds/second^2
a_{f1}	16*	2^{-43}		seconds/second
a_{f0}	22*	2^{-31}		seconds

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation.
*** Unless otherwise indicated in this column, effective range is the maximum range.

Table A-3. User range accuracy

URA	Accuracy
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

3.1.1.3.1.3 Health. The transmitting satellite 6-bit health indication shall be provided by bits 17 through 22 of word 3. The MSB shall indicate a summary of the health of the navigation data, where:

a) 0 = all navigation data are valid; and

b) 1 = some of the navigation data are not valid.

The 5 LSBs shall indicate the health of the signal components in accordance with 3.1.1.3.3.4. The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code in 3.1.1.3.3.5. Any satellite that does not have a certain capability shall be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a receiver standpoint and does not require that capability. Additional health data shall be given in subframes 4 and 5.

Note.— The data given in subframe 1 may differ from that shown in subframes 4 and/or 5 of other satellites since the latter may be updated at a different time.

3.1.1.3.1.4 Issue of data, clock (IODC). Bits 23 and 24 of word 3 in subframe 1 shall be the 2 MSBs of the 10-bit IODC term. Bits 1 through 8 of word 8 in subframe 1 shall contain the 8 LSBs of the IODC. The IODC shall indicate the issue number of data set. The transmitted IODC shall be different from any value transmitted by the satellite during the preceding 7 days.

Note.— The relationship between the IODC and the Issue of Data, Ephemeris (IODE) terms is defined in 3.1.1.3.2.2.

3.1.1.3.1.5 Estimated group delay differential. Bits 17 through 24 of word 7 shall contain the correction term, T_{GD}, to account for the effect of satellite group delay differential.

Note.— T_{GD} does not include any C/A to P(Y) code relative group delay error.

3.1.1.3.1.6 Satellite clock correction parameters. Bits 9 through 24 of word 8, bits 1 through 24 of word 9, and bits 1 through 22 of word 10 shall contain the parameters needed by the users for apparent satellite clock correction (t_{oc}, a_{f2}, a_{f1} and a_{f0}).

3.1.1.3.1.7 Reserved data fields. Reserved data fields shall be as indicated in Table A-4. All reserved data fields shall support valid parity within their respective words.

3.1.1.3.2 Subframes 2 and 3 - satellite ephemeris data. Subframes 2 and 3 shall contain the ephemeris representation of the transmitting satellite.

3.1.1.3.2.1 Ephemeris parameters. The ephemeris parameters shall be as indicated in Table A-5. For each parameter in subframe 2 and 3, the number of bits, the scale factor of the LSB, the range, and the units shall be as specified in Table A-6.

3.1.1.3.2.2 Issue of data, ephemeris (IODE). The IODE shall be an 8-bit number equal to the 8 LSBs of the 10-bit IODC of the same data set. The IODE shall be provided in both subframes 2 and 3 for the purpose of comparison with the 8 LSBs of the IODC term in subframe 1. Whenever these three terms do not match, as a result of a data set cutover, new data shall be collected. The transmitted IODE shall be different from any value transmitted by the satellite during the preceding six hours (Note 1). Any change in the subframe 2 and 3 data shall be accomplished in concert with a change in both IODE words. Change to new data sets shall occur only on hour boundaries except for the first data set of a new upload. Additionally, the t_{oe} value, for at least the first data set transmitted by a satellite after an upload, shall be different from that transmitted prior to the change (Note 2).

Table A-4. Subframe 1 reserved data fields

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
Week number	10	1		weeks
Satellite accuracy	4			
Satellite health	6	1		discretes
T_{GD}	8*	2^{-31}		seconds
IODC	10			
t_{oc}	16	2^{4}	604 784	seconds
a_{f2}	8*	2^{-55}		seconds/second^2
a_{f1}	16*	2^{-43}		seconds/second
a_{f0}	22*	2^{-31}		seconds

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

** See Figure B-6 for complete bit allocation.

*** Unless otherwise indicated in this column, effective range is the maximum range.

Table A-5. Ephemeris data

M_0	Mean anomaly at reference time
Δn	Mean motion difference from computed value
e	Eccentricity
$\sqrt{A}$	Square root of the semi-major axis
$OMEGA_0$	Longitude of ascending node of orbit plane at weekly epoch
i_0	Inclination angle at reference time
ω	Argument of perigee
OMEGADOT	Rate of right ascension
iDOT	Rate of inclination angle
C_{uc}	Amplitude of the cosine harmonic correction term to the argument of latitude
C_{us}	Amplitude of the sine harmonic correction term to the argument of latitude
C_{rc}	Amplitude of the cosine harmonic correction term to the orbit radius
C_{rs}	Amplitude of the sine harmonic correction term to the orbit radius
C_{ic}	Amplitude of the cosine harmonic correction term to the angle of inclination
C_{is}	Amplitude of the sine harmonic correction term to the angle of inclination
t_{oe}	Reference time, ephemeris
IODE	Issue of data, ephemeris

Table A-6. Ephemeris parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
IODE	8			
C_{rs}	16*	2^{-5}		metres
Δn	16*	2^{-43}		semi-circles/second
M_0	32*	2^{-31}		semi-circles
C_{uc}	16*	2^{-29}		radians
e	32	2^{-33}	0.03	dimensionless
C_{us}	16*	2^{-29}		radians
$\sqrt{A}$	32	2^{-19}		$\text{metres}^{1/2}$
t_{oe}	16	2^{4}	604 784	seconds
C_{ic}	16*	2^{-29}		radians
$OMEGA_0$	32*	2^{-31}		semi-circles
C_{is}	16*	2^{-29}		radians
i_0	32*	2^{-31}		semi-circles
C_{rc}	16*	2^{-5}		metres
ω	32*	2^{-31}		semi-circles
OMEGADOT	24*	2^{-43}		semi-circles/second
iDOT	14*	2^{-43}		semi-circles/second

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.

** See Figure B-6 for complete bit allocation in subframe.

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

Note 1.— The IODE/IODC terms provide the receiver with a means for detecting any changes in the ephemeris/clock representation parameters.

Note 2.— The first data set may change (3.1.1.2.2) at any time during the hour and therefore may be transmitted by the satellite for less than 1 hour.

3.1.1.3.2.3 Reserved data fields. Within word 10, subframe 2, bits 17 through 22 shall be reserved. Reserved data fields shall support the valid parity within their respective words.

3.1.1.3.3 Subframes 4 and 5 - support data. Both subframes 4 and 5 shall be subcommutated 25 times each. With the possible exception of "reserved" pages and explicit repeats, each page shall contain different data in words 3 through 10. The pages of subframe 4 shall use 6 different formats, and the pages of subframe 5 shall use two different formats as indicated in Figure B-6.

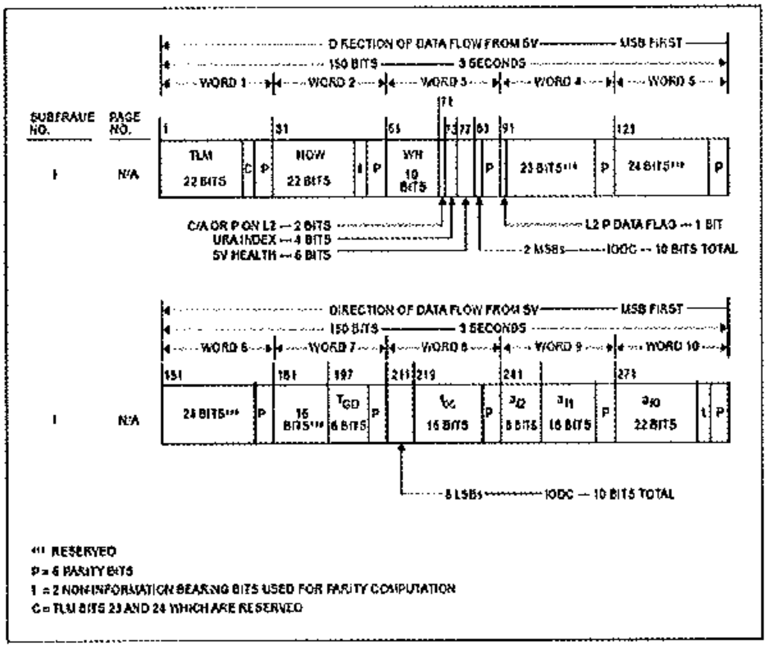

Figure B-6 Data format (1 of 11)

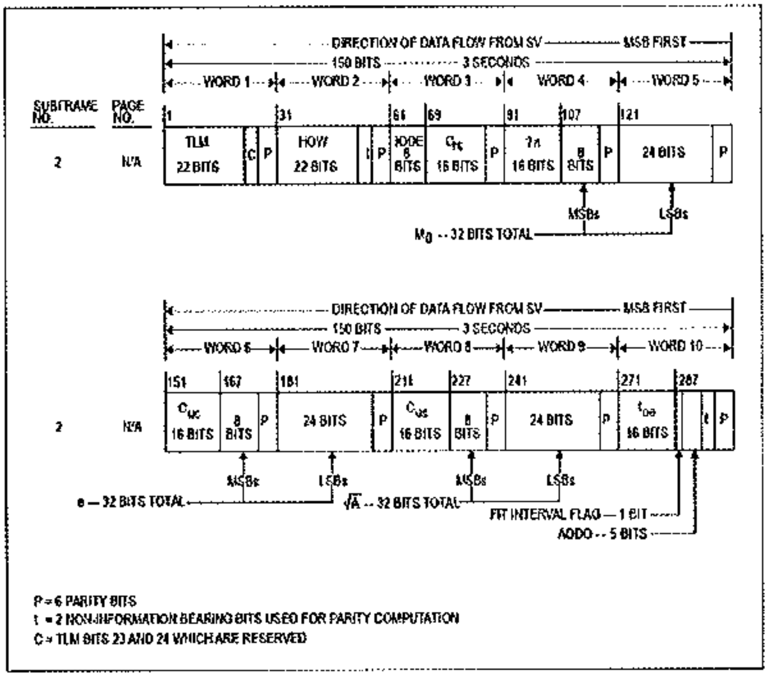

Figure B-6 Data format (2 of 11)

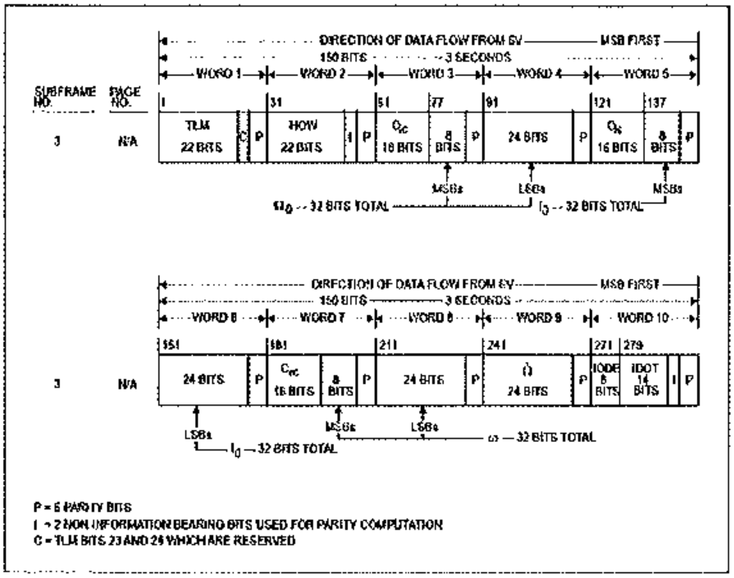

Figure B-6 Data format (3 of 11)

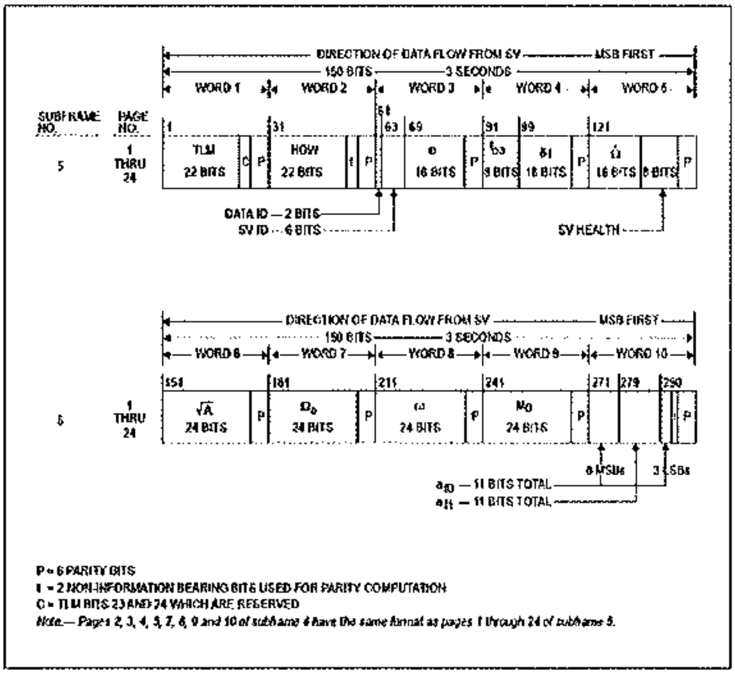

Figure B-6 Data format (4 of 11)

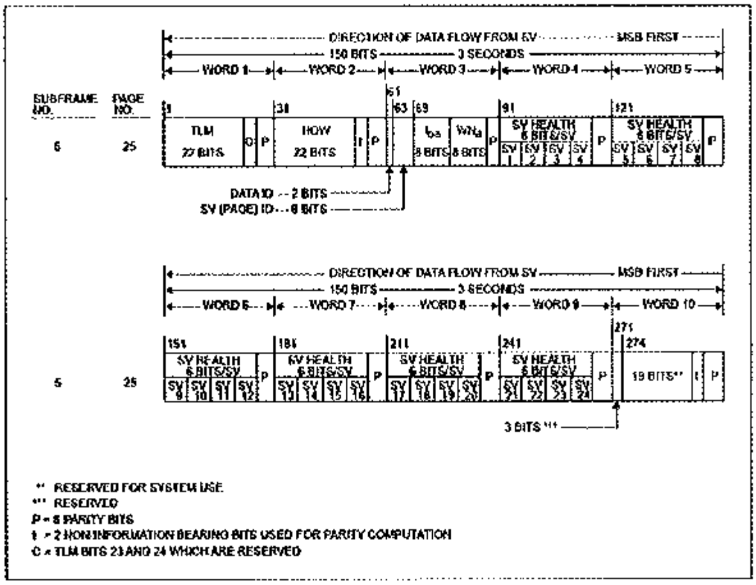

Figure B-6 Data format (5 of 11)

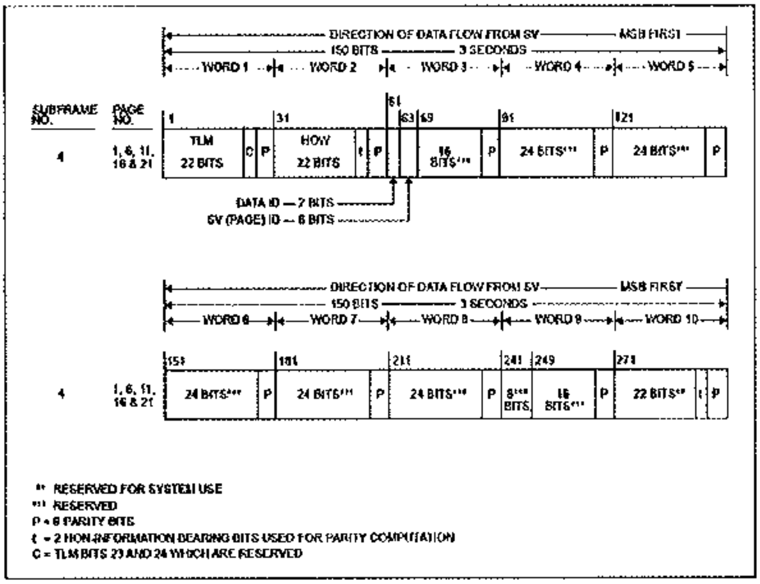

Figure B-6 Data format (6 of 11)

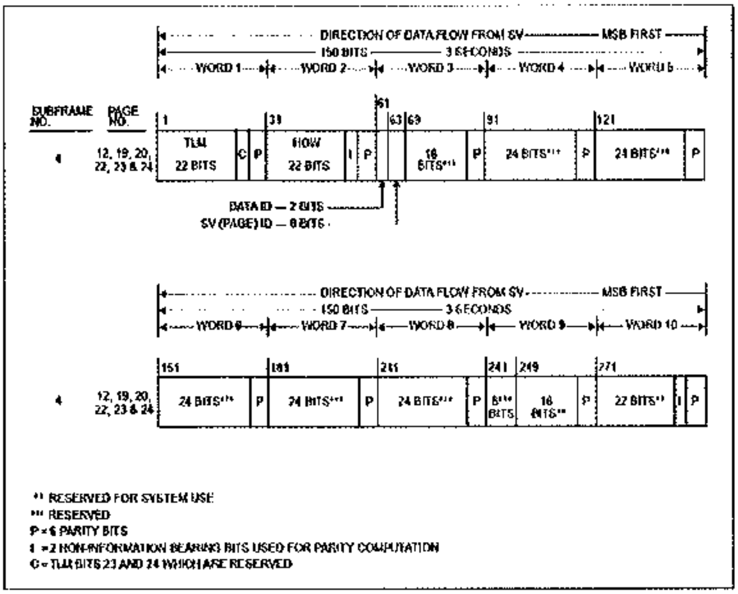

Figure B-6 Data format (7 of 11)

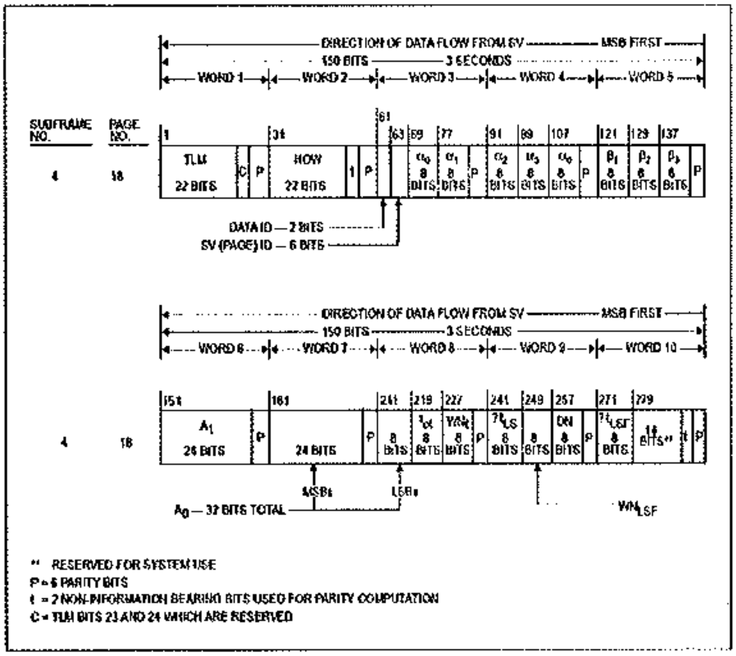

Figure B-6 Data format (8 of 11)

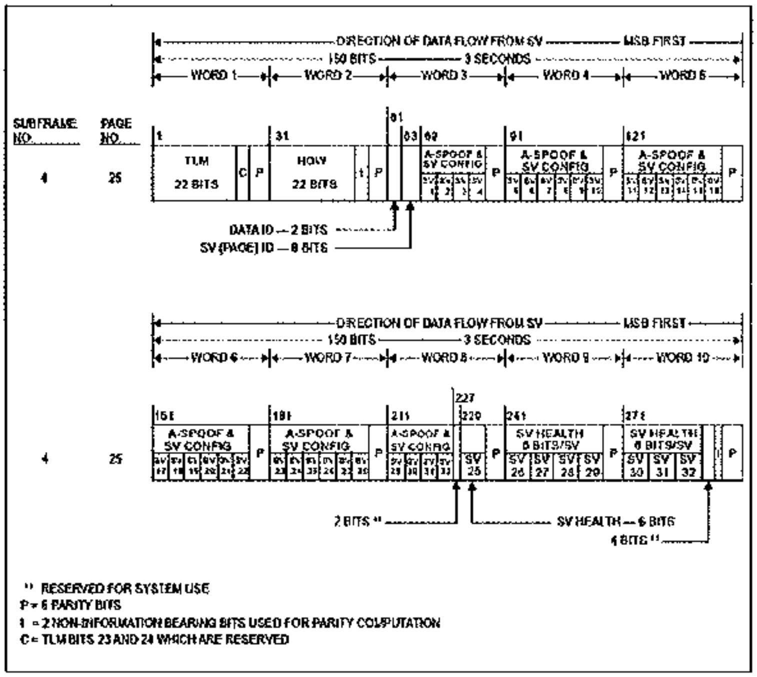

Figure B-6 Data format (9 of 11)

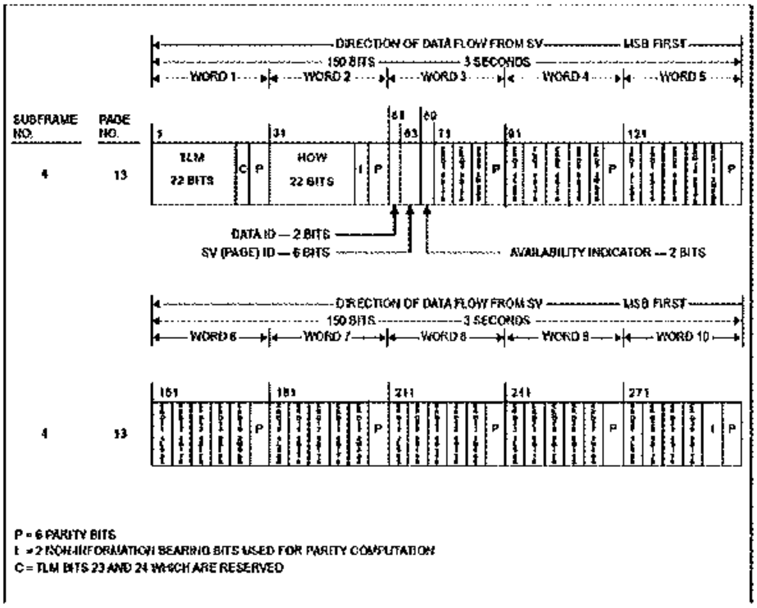

Figure B-6 Data format (10 of 11)

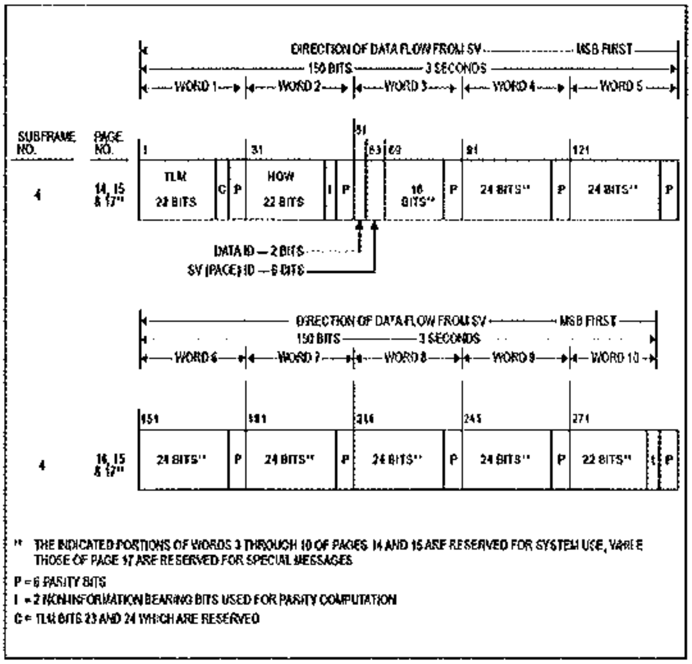

Figure B-6 Data format (11 of 11)

Pages of subframe 4 shall be as follows:

(a) Pages 2, 3, 4, 5, 7, 8, 9 and 10: almanac data for satellites 25 through 32 respectively. If the 6-bit health status word of page 25 is set to 6 "ones" (3.1.1.3.3.4) then the satellite ID of the page shall not have a value in the range of 25 through 32;

Note.— These pages may be designed for other functions. The format and content for each page is defined by the satellite ID of that page.

(b) Page 17: special messages;

(c) Page 18: ionospheric and UTC data;

(d) Page 25: satellite configurations for 32 satellites; and

(e) Pages 1, 6, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23 and 24: reserved.

Pages of subframe 5 shall be as follows:

a) Pages 1 through 24: almanac data for satellite 1 through 24; and

b) Page 25: satellite health data for satellite 1 through 24, the almanac reference time and the almanac reference week number.

3.1.1.3.3.1 Data ID. The two MSBs of word 3 in each page shall contain the data ID that defines the applicable GPS navigation data structure. The data ID shall be as indicated in Table A-7 in accordance with the following:

a) for those pages which are assigned to contain the almanac data of one specific satellite, the data ID shall define the data structure utilized by that satellite whose almanac data are contained in that page;

b) for all other pages, the data ID shall denote the data structure of the transmitting satellite; and

c) data ID "1" (denoted by binary state 00) shall not be used.

3.1.1.3.3.2 Satellite ID. The satellite ID shall be provided by bits 3 through 8 of word 3 in each page. The satellite IDs shall be utilized two ways:

a) for those pages which contain the almanac data of a given satellite, the satellite ID shall be the same number that is assigned the PRN code phase of that satellite in accordance with Table A-1; and

b) for all other pages the satellite ID assigned in accordance with Table A-7 shall serve as the "page ID". IDs 1 through 32 shall be assigned to those pages which contain the almanac data of specific satellites (pages 1 through 24 of subframe 5 and pages 2 through 5, and 7 through 10 of subframe 4). The "0" ID (binary all zeros) shall be assigned to indicate a dummy satellite, while IDs 51 through 63 shall be utilized for pages containing other than almanac data for a specific satellite (Notes 1 and 2).

Note 1.— Specific IDs are reserved for each page of subframes 4 and 5; however, the satellite ID of pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 may change for each page to reflect the alternate contents for that page.

Note 2.— The remaining IDs (33 through 50) are unassigned.

Table A-7. Data IDs and satellite IDs in subframes 4 and 5

	Subframe 4		Subframe 5	
Page	Data ID	Satellite ID*	Data ID	Satellite ID*
1	***	57	**	1
2****	**	25	**	2
3****	**	26	**	3
4****	**	27	**	4
5****	**	28	**	5
6	***	57	**	6
7****	**	29	**	7
8****	**	30	**	8
9****	**	31	**	9
10****	**	32	**	10
11	***	57	**	11
12	***	62	**	12
13	***	52	**	13
14	***	53	**	14
15	***	54	**	15
16	***	57	**	16
17	***	55	**	17
18	***	56	**	18
19	***	58*****	**	19
20	***	59*****	**	20
21	***	57	**	21
22	***	60*****	**	22
23	***	61*****	**	23
24	***	62	**	24
25	***	63	***	51

* "0" indicates "dummy" satellite. When using "0" to indicate a dummy satellite, the data ID of the transmitting satellite is used.

** Data ID of that satellite whose satellite ID appears in that page.

*** Data ID of transmitting satellite.

**** Pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 may contain almanac data for satellites 25 through 32, respectively, or data for other functions as identified by a different satellite ID from the value shown.

***** Satellite ID may vary.

3.1.1.3.3.3 Almanac. Pages 1 through 24 of subframe 5, as well as pages 2 through 5 and 7 through 10 of subframe 4 shall contain the almanac data and a satellite health status word (3.1.1.3.3.4) for up to 32 satellites. The almanac data shall be a reduced-precision subset of the clock and ephemeris parameters. The data shall occupy all bits of words 3 through 10 of each page except the 8 MSBs of word 3 (data ID and satellite ID), bits 17 through 24 of word 5 (satellite health), and the 50 bits devoted to parity. The number of bits, the scale factor (LSB), the range and the units of the almanac parameters shall be as indicated in Table A-8. The almanac message for any dummy satellite shall contain alternating "ones" and "zeros" with a valid parity.

3.1.1.3.3.3.1 Almanac reference time. The almanac reference time, t_{oa}, shall be a multiple of 2^{12} seconds occurring approximately 70 hours after the first valid transmission time for this almanac data set. The almanac shall be updated often enough to ensure that GPS time, t, will differ from t_{oa} by less than 3.5 days during the transmission period. The almanac parameters shall be updated at least once every 6 days during normal operations.

3.1.1.3.3.3.2 Almanac time parameters. The almanac time parameters shall consist of an 11-bit constant term (a_{f0}) and an 11-bit first order term (a_{f1}).

3.1.1.3.3.3.3 Almanac reference week. Bits 17 through 24 of word 3 in page 25 of subframe 5 shall indicate the number of the week (WN_a) to which the almanac reference time (t_{oa}) is referenced. The WN_a term shall consist of the 8 LSBs of the full week number. Bits 9 through 16 of word 3 in page 25 of subframe 5 shall contain the value of t_{oa} that is referenced to this WN_a.

3.1.1.3.3.4 Health summary. Subframes 4 and 5 shall contain two types of satellite health data:

a) each of the 32 pages that contain the clock/ephemeris related almanac data shall provide an 8-bit satellite health status word regarding the satellite whose almanac data they carry; and

b) the 25th pages of subframes 4 and 5 jointly shall contain 6-bit health data for up to 32 satellites.

3.1.1.3.3.4.1 The 8-bit health status words shall occupy bits 17 through 24 of word 5 in those 32 pages that contain the almanac data for individual satellites. The 6-bit health status words shall occupy the 24 MSBs of words 4 through 9 in page 25 of subframe 5, and bits 19 through 24 of word 8, the 24 MSBs of word 9, and the 18 MSBs of word 10 in page 25 of subframe 4.

Table A-8. Almanac parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
e	16	2^{-21}		dimensionless
t_{oa}	8	2^{12}	602 112	seconds
δ_i****	16*	2^{-19}		semi-circles
OMEGADOT	16*	2^{-38}		semi-circles/second
$\sqrt{A}$	24*	2^{-11}		metres$^{1/2}$
$OMEGA_0$	24*	2^{-23}		semi-circles
ω	24*	2^{-23}		semi-circles
M_0	24*	2^{-23}		semi-circles
a_{f0}	11*	2^{-20}		seconds
a_{f1}	11*	2^{-38}		seconds/second

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.

** See Figure B-6 for complete bit allocation in subframe.

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

**** Relative to i_0 = 0.30 semi-circles.

3.1.1.3.3.4.2 The 3 MSBs of the 8-bit health status words shall indicate health of the navigation data in accordance with the code given in Table A-9. The 6-bit words shall provide a 1-bit summary of the navigation data's health status in the MSB position in accordance with 3.1.1.3.1.3. The 5 LSBs of both the 8-bit and the 6-bit health status words shall provide the health status of the satellite's signal components in accordance with the code given in Table A-10.

Table A-9. Navigation data health indication

Bit position in page			Indication
137	138	139	
0	0	0	ALL DATA OK
0	0	1	PARITY FAILURE — some or all parity bad
0	1	0	TLM/HOW FORMAT PROBLEM — any departure from standard format (e.g. preamble misplaced and/or incorrect), except for incorrect Z-count, as reported in HOW
0	1	1	Z-COUNT in HOW BAD — any problem with Z-count value not reflecting actual code phase
1	0	0	SUBFRAMES 1, 2, 3 — one or more elements in words 3 through 10 of one or more subframes are bad
1	0	1	SUBFRAMES 4, 5 — one or more elements in words 3 through 10 of one or more subframes are bad
1	1	0	ALL UPLOADED DATA BAD — one or more elements in words 3 through 10 of any one (or more) subframes are bad
1	1	1	ALL DATA BAD — TLM word and/or HOW and one or more elements in any one (or more) subframes are bad

Table A-10. Codes for health of satellite signal components

MSB				LSB	Indication
0	0	0	0	0	ALL SIGNALS OK
1	1	1	0	0	SATELLITE IS TEMPORARILY OUT — do not use this satellite during current pass ___
1	1	1	0	1	SATELLITE WILL BE TEMPORARILY OUT — use with caution ___
1	1	1	1	0	SPARE
1	1	1	1	1	MORE THAN ONE COMBINATION WOULD BE REQUIRED TO DESCRIBE ANOMALIES, EXCEPT THOSE MARKED BY ___
All other combinations					SATELLITE EXPERIENCING CODE MODULATION AND/OR SIGNAL POWER LEVEL TRANSMISSION PROBLEMS. The user may experience intermittent tracking problems if satellite is acquired.

3.1.1.3.3.4.3 A special meaning shall be assigned, to the 6 "ones" combination of the 6-bit health status words in the 25th pages of subframes 4 and 5; it shall indicate that "the satellite which has that ID is not available and there may be no data regarding that satellite in the page of subframe 4 or 5 that is assigned to normally contain the almanac data of that satellite".

Note.– This special meaning applies to the 25th pages of subframes 4 and 5 only. There may be data regarding another satellite in the almanac page referred to above as defined in 3.1.1.3.3.3.

3.1.1.3.3.4.4 The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code in 3.1.1.3.3.5. Accordingly, any satellite that does not have a certain capability shall be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a receiver standpoint and does not require that capability. The predicted health data shall be updated at the time of upload.

Note 1.— The transmitted health data may not correspond to the actual health of the transmitting satellite or other satellites in the constellation.

Note 2.— The data given in subframes 1, 4 and 5 of the other satellites may differ from that shown in subframes 4 and/or 5 since the latter may be updated at a different time.

3.1.1.3.3.5 Satellite configuration summary. Page 25 of subframe 4 shall contain a 4-bit-long term for each of up to 32 satellites to indicate the configuration code of each satellite. These 4-bit terms shall occupy bits 9 through 24 of words 3, the 24 MSBs of words 4 through 7, and the 16 MSBs of word 8, all in page 25 of subframe 4. The MSB of each 4-bit term shall indicate whether anti-spoofing is activated (MSB = 1) or not activated (MSB = 0). The 3 LSBs shall indicate the configuration of each satellite using the following code:

Code	Satellite configuration
001	Block II/IIA/IIR satellite
010	Block IIR-M satellite
011	Block IIF satellite

3.1.1.3.3.6 UTC parameters. Page 18 of subframe 4 shall include:

a) the parameters needed to relate GPS time to UTC time; and

b) notice to the user regarding the scheduled future or past (relative to navigation message upload) value of the delta time due to leap seconds (t_{LSF}), together with the week number (WN_{LSF}) and the day number (DN) at the end of which the leap second becomes effective. "Day one" shall be the first day relative to the end/start of week and the WN_{LSF} value consists of the 8 LSBs of the full week number. The absolute value of the difference between the untruncated WN and WN_{LSF} values shall not exceed 127.

Note.— The user is expected to account for the truncated nature of this parameter as well as truncation of WN, WN_t and WN_{LSF} due to rollover of the full week number (3.1.1.2.6.2).

3.1.1.3.3.6.1 The 24 MSBs of words 6 through 9, and the 8 MSBs of word 10 in page 18 of subframe 4 shall contain the parameters related to correlating UTC time with GPS time. The bit length, scale factors, ranges, and units of these parameters shall be as specified in Table A-11.

3.1.1.3.3.7 Ionospheric parameters. The ionospheric parameters that allow the GPS SPS user to utilize the ionospheric model for computation of the ionospheric delay shall be contained in page 18 of subframe 4 as specified in Table A-12.

3.1.1.3.3.8 Special message. Page 17 of subframe 4 shall be reserved for special messages.

Table A-11. UTC parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
A_0	32*	2^{-30}		seconds
A_1	24*	2^{-50}		seconds/second
Δt_{LS}	8*	1		seconds
t_{ot}	8	2^{12}	602 112	seconds
WN_t	8	1		weeks
WN_{LSF}	8	1		weeks
DN	8****	1	7	days
Δt_{LSF}	8*	1		seconds

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation in subframe.
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.
**** Right justified.

Table A-12. UTC parameters

D_1	=	$d_1 \oplus D^*_{30}$
D_2	=	$d_2 \oplus D^*_{30}$
D_3	=	$d_3 \oplus D^*_{30}$
•		•
•		•
•		•
•		•
D_{24}	=	$d_{24} \oplus D^*_{30}$
D_{25}	=	$D^*_{29} \oplus d_1 \oplus d_2 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_{10} \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{17} \oplus d_{18} \oplus d_{20} \oplus d_{23}$
D_{26}	=	$D^*_{30} \oplus d_2 \oplus d_3 \oplus d_4 \oplus d_6 \oplus d_7 \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{18} \oplus d_{19} \oplus d_{21} \oplus d_{24}$
D_{27}	=	$D^*_{29} \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_5 \oplus d_7 \oplus d_8 \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{19} \oplus d_{20} \oplus d_{22}$
D_{28}	=	$D^*_{30} \oplus d_2 \oplus d_4 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{20} \oplus d_{21} \oplus d_{23}$
D_{29}	=	$D^*_{30} \oplus d_1 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_7 \oplus d_9 \oplus d_{10} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{18} \oplus d_{21} \oplus d_{22} \oplus d_{24}$
D_{30}	=	$D^*_{29} \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{10} \oplus d_{11} \oplus d_{13} \oplus d_{15} \oplus d_{19} \oplus d_{22} \oplus d_{23} \oplus d_{24}$

where:

$D_1, D_2, D_3, \ldots D_{29}, D_{30}$ are the bits transmitted by the satellite;
$D_{25}, \ldots D_{30}$ are the computed parity bits;
$d_1, d_2, \ldots d_{24}$ are the source data bits;
$\oplus$ is the Modulo-2 or "Exclusive-Or" operation; and
* is used to identify the last two bits of the previous word of the subframe.

3.1.2.1 Parity algorithm. GPS parity algorithms are defined as indicated in Table A-14.

3.1.2.2 Satellite clock correction parameters. GPS system time t is defined as:

$$t = t_{sv} - (\Delta t_{sv})_{L1}$$

where

t	=	GPS system time (corrected for beginning and end-of-week crossovers);
t_{sv}	=	satellite time at transmission of the message;
$(\Delta t_{sv})_{L1}$	=	the satellite PRN code phase offset;
$(\Delta t_{sv})_{L1}$	=	$a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r - T_{GD}$

where

a_{f0}, a_{f1} and a_{f2} and t_{oc}, are contained in subframe 1; and
Δt_r = the relativistic correction term (seconds)
Δt_r = $Fe\sqrt{A}\sin E_k$

where

e and A are contained in subframes 2 and 3;
E_k is defined in Table B-15; and

$$F = \frac{-2(\mu)^{1/2}}{c^2} = -4.442807633(10)^{-10}\ s/m^{1/2}$$

where

μ = WGS-84 universal gravitational parameter ($3.986005 \times 10^{14}\ m^3/s^2$)
c = the speed of light in a vacuum (2.99792458×10^8 m/s)

Note. The value of t is intended to account for the beginning or end-of-week crossovers. That is, if the quantity $t-t_{oc}$ is greater than 302 400 seconds, subtract 604 800 seconds from t. If the quantity $t-t_{oc}$ is less than −302 400 seconds, add 604 800 seconds to t.

3.1.2.3 Satellite position. The current satellite position (X_k, Y_k, Z_k) is defined as shown in Table A-15.

3.1.2.4 Ionospheric correction. The ionospheric correction (T_{iono}) is defined as:

$$T_{iono} = \begin{cases} F \times \left[5.0\times10^{-9} + AMP\left(1-\frac{x^2}{2}+\frac{x^4}{24}\right)\right], & |x| < 1.57 \\ F \times (5.0\times10^{-9}) +, & |x| \geq 1.57 \end{cases} \quad \text{(seconds)}$$

where

$$AMP = \begin{cases} \sum_{n=0}^{3} \alpha_n \phi_m^n, & AMP \geq 0 \\ \text{If } AMP < 0, & AMP = 0 \end{cases} \quad \text{(seconds)}$$

$$x = \frac{2\pi(t-50\ 400)}{PER}, \text{ (radians)}$$

$$\text{PER}=\begin{cases}\sum_{n=0}^{3}\beta_n\phi_m^n, & \text{PER}\geq 72\,000\\ \text{if PER} < 72\,000, \text{PER} = 72\,000\end{cases} \quad \text{(seconds)}$$

$$\text{PER}=\begin{Bmatrix}\sum_{n=0}^{3}\beta_n\phi_m^n, & \text{PER}\geq 72\,000\\ \text{if PER} < 72\,000, \text{PER} = 72\,000\end{Bmatrix} \text{(seconds)}$$

$F = 1.0 + 16.0[0.53 - E]^3$

α_n and β_n are the satellite transmitted data words with n = 0, 1, 2 and 3

$\phi_m = \phi_i + 0.064 \cos(\lambda_i - 1.617)$ (semi-circles)

$\lambda_i = \lambda_u + \dfrac{\psi \sin A}{\cos\phi_i}$ (semi-circles)

$\bar{\phi}_i = \phi_u + \psi \cos A$ (semi-circles)

$$\phi_i = \begin{Bmatrix}\phi_i = \bar{\phi}_i \text{ if } |\bar{\phi}_i| \leq 0.416\\ \phi_i = +0.416 \text{ if } \bar{\phi}_i > 0.416,\\ \phi_i = -0.416 \text{ if } \bar{\phi}_i < -0.416\end{Bmatrix} \text{(semi-circles)}$$

$\psi = \dfrac{0.0137}{E+0.11} - 0.022$ (semi-circles)

t = $4.32 \times 10^4 \lambda_i$ + GPS time (seconds) where $0 \leq t < 86\,400$, therefore: if $t \geq 86\,400$ seconds, subtract 86 400 seconds; and if $t < 0$ seconds, add 86 400 seconds

E = satellite elevation angle

3.1.2.4.1 The terms used in computation of ionospheric delay are as follows:

a) Satellite transmitted terms

α_n	=	the coefficients of a cubic equation representing the amplitude of the vertical delay (4 coefficients = 8 bits each)
β_n	=	the coefficients of a cubic equation representing the period of the model (4 coefficients = 8 bits each)

b) Receiver generated terms

E	=	elevation angle between the user and satellite (semi-circles)
A	=	azimuth angle between the user and satellite, measured clockwise positive from the true North (semi-circles)
ϕ_u	=	user geodetic latitude (semi-circles) WGS-84
λ_u	=	user geodetic longitude (semi-circles) WGS-84
GPS time	=	receiver computed system time

c) Computed terms

x	=	phase (radians)
F	=	obliquity factor (dimensionless)
t	=	local time (seconds)
ϕ_m	=	geomagnetic latitude of the earth projection of the ionospheric intersection point (mean ionospheric height assumed 350 km) (semi-circles)
λ_i	=	geomagnetic longitude of the earth projection of the ionospheric intersection point (semi-circles)
ϕ_i	=	geomagnetic latitude of the earth projection of the ionospheric intersection point (semi-circles)
ψ	=	earth's central angle between user position and earth projection of ionospheric intersection point (semi-circles)

Table A-15. Elements of coordinate systems

$A = (\sqrt{A})^2$	Semi-major axis
$n_0 = \sqrt{\frac{\mu}{A^3}}$	Computed mean motion
$t_k = t - t_{oe}$	Time from ephemeris reference epoch*
$n = n_0 + \Delta n$	Corrected mean motion
$M_k = M_0 + n t_k$	Mean anomaly
$M_k = E_k - e \sin E_k$	Kepler's equation for eccentric anomaly (may be solved by iteration)
$v_k = \tan^{-1}\left\{\frac{\sin v_k}{\cos v_k}\right\} = \tan^{-1}\left\{\frac{\sqrt{1-e^2}\sin E_k/(1-e\cos E_k)}{(\cos E_k - e)/(1-e\cos E_k)}\right\}$	True anomaly
$E_k = \cos^{-1}\left\{\frac{e+\cos v_k}{1+e\cos v_k}\right\}$	Eccentric anomaly
$\Phi_k = v_k + \omega$	Argument of latitude
	Second Harmonic Perturbations
$\delta u_k = C_{us}\sin 2\Phi_k + C_{uc}\cos 2\Phi_k$	Argument of latitude correction
$\delta r_k = C_{rs}\sin 2\Phi_k + C_{rc}\sin 2\Phi_k$	Radius correction
$\delta i_k = C_{ic}\cos 2\Phi_k + C_{is}\sin 2\Phi_k$	Inclination correction
$u_k = \Phi_k + \delta u_k$	Corrected argument of latitude
$r_k = A(1 - e\cos E_k) + \delta r_k$	Corrected radius
$i_k = i_0 + \delta i_k + (IDOT)t_k$	Corrected inclination
$x'_k = r_k\cos u_k$ $y'_k = r_k\sin u_k$	Positions in orbital plane
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node
$x_k = x'_k\cos\Omega_k - y'_k\cos i_k\sin\Omega_k$ $y_k = x'_k\sin\Omega_k + y'_k\cos i_k\cos\Omega_k$ $z_k = y'_k\sin i_k$	Earth-centred, earth-fixed coordinates

* t is GPS system time at time of transmission, i.e. GPS time corrected for transit time (range/speed of light). Furthermore, t_k is the actual total time difference between the time t and the epoch time t_{oe} and must account for beginning or end-of-week crossovers. That is, if t_k is greater than 302 400 seconds, subtract 604 800 seconds from t_k. If t_k is less than −302 400 seconds, add 604 800 seconds to t_k.

3.1.3 **Aircraft Elements**

3.1.3.1 GNSS (GPS) Receiver

3.1.3.1.1 Satellite exclusion. The receiver shall exclude any marginal or unhealthy satellite.

Note.— Conditions indicating that a satellite is "healthy", "marginal" or "unhealthy" can be found in the United States Department of Defense, Global Positioning System – Standard Positioning Service – Performance Standard, 4th Edition, September 2008, Section 2.3.2.

3.1.3.1.2 Satellite tracking. The receiver shall provide the capability to continuously track a minimum of four satellites and generate a position solution based upon those measurements.

3.1.3.1.3 Doppler shift. The receiver shall be able to compensate for dynamic Doppler shift effects on nominal SPS signal carrier phase and C/A code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.1.3.1.4 Resistance to interference. The receiver shall meet the requirements for resistance to interference as specified in regulation 117 - 121

3.1.3.1.5 Application of clock and ephemeris data. The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution. The receiver shall monitor the IODC and IODE values, and to update ephemeris and clock databased upon a detected change in one or both of these values. The SPS receiver shall use clock and ephemeris data with corresponding IODC and IODE values for a given satellite.

3.1.4 **Time**

GPS time shall be referenced to a UTC (as maintained by the U.S. Naval Observatory) zero time-point defined as midnight on the night of 5 January 1980/morning of 6 January 1980. The largest unit used in stating GPS time shall be 1 week, defined as 604 800 seconds. The GPS time scale shall be maintained to be within 1 microsecond of UTC (Modulo 1 second) after correction for the integer number of leap seconds difference. The navigation data shall contain the requisite data for relating GPS time to UTC.

3.2 Global navigation satellite system (GLONASS) channel of standard accuracy (CSA) (L1)

Note. - In this section the term GLONASS refers to all satellites in the constellation. Standards relating only to GLONASS-M satellites are qualified accordingly.

3.2.1 Non-Aircraft Elements

3.2.1.1 RF Characteristics

3.2.1.1.1 Carrier frequencies. The nominal values of L1 carrier frequencies shall be as defined by the following expressions:

$$f_{k1} = f_{01} + k\Delta f_1$$

where

k = −7, ..., 0, 1, ..., 6 are carrier numbers (frequency channels) of the signals transmitted by GLONASS satellites in the L1 sub-band;

f_{01} = 1 602 MHz; and
Δf_1 = 0.5625 MHz.

Carrier frequencies shall be coherently derived from a common on-board time/frequency standard. The nominal value of frequency, as observed on the ground, shall be equal to 5.0 MHz. The carrier frequency of a GLONASS satellite shall be within $\pm 2 \times 10^{-11}$ relative to its nominal value f_k.

Note 1.— The nominal values of carrier frequencies for carrier numbers k are given in Table B-16.

Note 2.— For GLONASS-M satellites, the L2 channel of standard accuracy (CSA) navigation signals will occupy the 1 242.9375 – 1 251.6875 MHz ±0.511 MHz bandwidth as defined by the following expressions:

$$f_{k2} = f_{02} + k\Delta f_2,$$

$$f_{02} = 1\ 246\ \text{MHz};\ \Delta f_2 = 0.4375\ \text{MHz}.$$

For any given value of k the ratio of carrier frequencies of L1 and L2 sub-bands will be equal to:

$$\frac{f_{k2}}{f_{k1}} = \frac{7}{9}$$

Table A-16. L1 carrier frequencies

Carrier number	H^A_n, (see 3.2.1.3.4)	Nominal value of frequency in L1 sub-band (MHz)
06	6	1 605.3750
05	5	1 604.8125
4	4	1 604.2500
3	3	1 603.6875
2	2	1 603.1250
1	1	1 602.5625
0	0	1 602.0000
−1	31	1 601.4375
−2	30	1 600.8750
−3	29	1 600.3125
−4	28	1 599.7500
−5	27	1 599.1875
−6	26	1 598.6250
−7	25	1 598.0625

3.2.1.1.2 Carrier phase noise. The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth provides the accuracy of carrier phase tracking not worse than 0.1 radian (1 sigma).

3.2.1.1.3 GLONASS pseudo-random code generation. The pseudo-random ranging code shall be a 511-bit sequence that is sampled at the output of the seventh stage of a 9-stage shift register. The initialisation vector to generate this sequence shall be "111111111". The generating polynomial that corresponds to the 9-stage shift register shall be:

$$G(x) = 1 + x^5 + x^9.$$

3.2.1.1.4 Spurious emissions. The power of the transmitted RF signal beyond the GLONASS allocated bandwidth shall not be more than –40 dB relative to the power of the unmodulated carrier.

Note 1.— GLONASS satellites launched during 1998 to 2005 and beyond use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 660 – 1 670 MHz band.

Note 2.— GLONASS satellites launched beyond 2005 use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 610.6 – 1 613.8 MHz and 1 660 – 1 670 MHz bands.

3.2.1.1.5 Correlation loss. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 0.8 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 1.022 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and a 1.022 MHz bandwidth.

3.2.1.2 Data Structure

3.2.1.2.1 General. The navigation message shall be transmitted as a pattern of digital data which are coded by Hamming code and transformed into relative code. Structurally, the data pattern shall be generated as continuously repeating superframes. The superframe shall consist of the frames and the frames shall consist of the strings. The boundaries of strings, frames and superframes of navigation messages from different GLONASS satellites shall be synchronized within 2 milliseconds.

3.2.1.2.2 Superframe structure. The superframe shall have a 2.5-minute duration and shall consist of 5 frames. Within each superframe a total content of non-immediate information (almanac for 24 GLONASS satellites) shall be transmitted.

Note.— Superframe structure with indication of frame numbers in the superframe and string numbers in the frames is shown in Figure B-7.

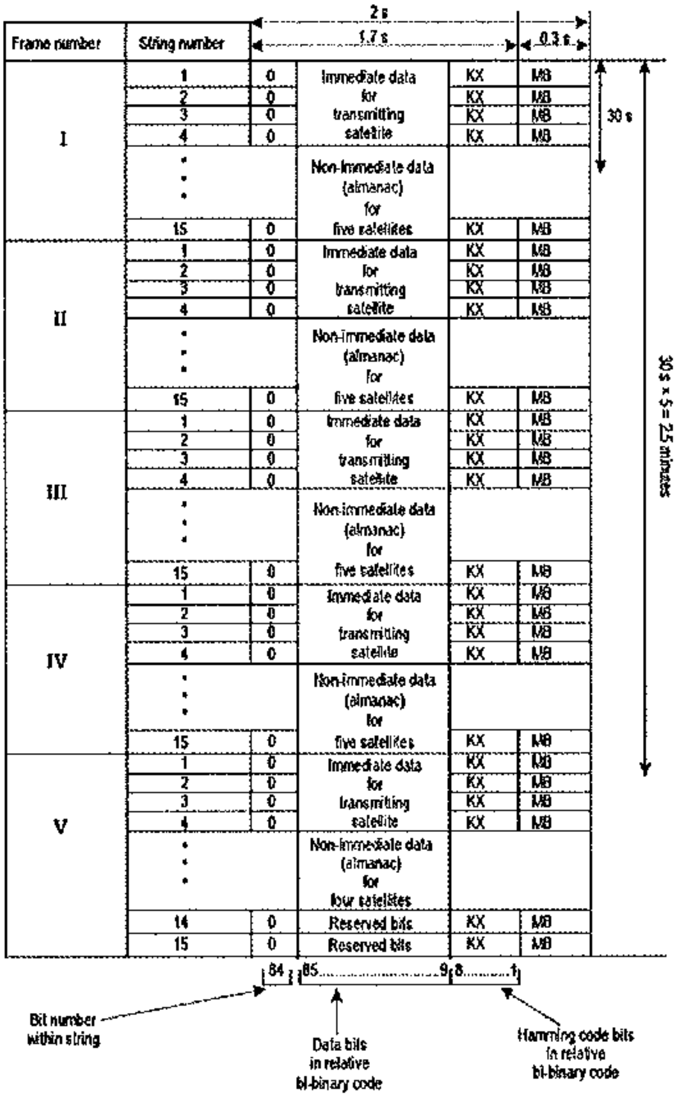

Figure B-7. Superframe structure

3.2.1.2.3 Frame structure. Each frame shall have a 30-second duration and shall consist of 15 strings. Within each frame the total content of immediate information (ephemeris and time parameters) for given satellite and a part of nonimmediate information (almanac) shall be transmitted. The frames 1 through 4 shall contain the part of almanac for 20 satellites (5 satellites per frame) and frame 5 shall contain the remainder of almanac for 4 satellites. The almanac for one satellite shall occupy two strings.

3.2.1.2.4 String structure. Each string shall have a 2-second duration and shall contain binary chips of data and time mark. During the last 0.3 second within this 2-second interval (at the end of each string) the time mark shall be transmitted. The time mark (shortened pseudo-random sequence) shall consist of 30 chips with a time duration for each chip of 10 milliseconds and having the following sequence:

1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0.

During the first 1.7 seconds within this 2-second interval (in the beginning of each string) 85 bits of data (each data bit of a 20 milliseconds duration) shall be transmitted in bi-binary format. The numbers of bits in the string shall be increased from right to left. Along with information bits (bit positions 9 through 84) the check bits of Hamming code (KX) (bit positions 1 through 8) shall be transmitted. The Hamming code shall have a code length of 4. The data of one string shall be separated from the data of adjacent strings by time mark (MB). The words of the data shall be registered by MSB ahead. In each string bit position, 85 shall be an idle chip ("0") and be transmitted first.

3.2.1.2.4.1 Strings 1 through 4. The information contained in strings 1 through 4 of each frame shall correspond to the satellite from which it is transmitted. This information shall not be changed within the superframe.

m	=	the string number within the frame;
t_k	=	the time referenced to the beginning of the frame within the current day. It is calculated according to the satellite time scale. The integer number of hours elapsed since the beginning of the current day is registered in the 5 MSBs. The integer number of minutes elapsed since the beginning of the current hour is registered in the next 6 bits. The number of 30-second intervals elapsed since the beginning of the current minute is registered in the one LSB. The beginning of the day according to the satellite time scale coincides with the beginning of the recurrent superframe;
t_b	=	the time interval within the current day according to UTC(SU) + 03 hours 00 min. The immediate data transmitted within the frame are referred to the middle of t_b. Duration of the time interval and therefore the maximum value of t_b depends on the value of the flag P1;
$\gamma_n(t_b)$	=	the relative deviation of predicted carrier frequency value of n-satellite from the nominal value at the instant t_b, i.e.

$$\gamma_n(t_b) = \frac{f_n(t_b) - f_{Hn}}{f_{Hn}}$$

where

$f_n(t_b)$	=	the forecast frequency of n-satellite clocks at an instant t_b;
f_{Hn}	=	the nominal value of frequency of n-satellite clocks,
$\tau_n(t_b)$	=	the correction to the n-satellite time t_n relative to GLONASS time t_c at an instant t_b, i.e. $\tau_n(t_b) = t_c(t_b) - t_n(t_b)$;
$x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$	=	the coordinates of n-satellite in PZ-90 coordinate system at an instant t_b;
$\dot{x}_n(t_b)$, $\dot{y}_n(t_b)$, $\dot{z}_n(t_b)$	=	the velocity vector components of n-satellite in PZ-90 coordinate system at an instant t_b;
$\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$	=	the acceleration components of n-satellite in PZ-90 coordinate system at an instant t_b, which are caused by effect of sun and moon;

3.2.1.2.4.2 Strings 5 through 15. Strings 5 through 15 of each frame shall contain GLONASS almanac for 4 or 5 satellites. The information contained in the fifth string shall be repeated in each frame of the superframe.

3.2.1.3 Data Content

3.2.1.3.1 Ephemeris and time parameters. The ephemeris and time parameters shall be as follows:

E_n = an indication of the "age" of the immediate information, i.e. a time interval elapsed since the instant of its calculation (uploading) until the instant t_b for n-satellite;

B_n = the health flag. Values greater than 3 indicate the fact of malfunction of given satellite;

P1 = a flag indicating the time interval between the current and previous value of the t_b parameters in minutes as shown:

P1	Time interval between adjacent values of t_b in minutes
0	0
1	30
10	45
11	60

P2 = a flag indicating whether the value of t_b is odd or even. A value of "1" indicates a 30-minute interval of service information transmit (t_b = 1, 3, 5 ...), a value of "0" indicates a 60-minute interval of service information transmit (t_b = 2, 6, 10 ...);

P3 = a flag indicating the number of satellites for which an almanac is transmitted within a given frame. "1" corresponds to 5 satellites and "0" corresponds to 4 satellites; and

$\Delta\tau_n$ = the time difference between the navigation RF signal transmitted in L2 sub-band and navigation RF signal transmitted in L1 sub-band by given satellite:

$$\Delta\tau_n = t_{f2} - t_{f1}$$

where t_{f1}, t_{f2} are the equipment delays in L1 and L2 sub-bands respectively, expressed in units of time.

3.2.1.3.2 Ephemeris and time parameters. The ephemeris and time parameters shall be as indicated in Table A-17. For the words for which numeric values may be positive or negative, the MSB shall be the sign bit. The chip "0" shall correspond to the "+" sign and the chip "1" shall correspond to the "–" sign.

3.2.1.3.3 Arrangement of the ephemeris and time parameters. Arrangements of the ephemeris and time parameters within a frame shall be as indicated in Table A-18.

3.2.1.3.4 Almanac parameters. The almanac parameters shall be as follows:

A = an index showing relation of this parameter with the almanac;

M^A_n = an index of the modification of n^A-satellite: "00" indicates GLONASS satellite, and "01" indicates GLONASS-M satellite;

τ_c = the GLONASS time scale correction to UTC(SU) time. The correction τ_c is given at the instant of day N^A;

N^A = the calendar day number within the 4-year period beginning since the leap year. The correction τ_c and other almanac data (almanac of orbit and almanac of phases) relate to this day number;

n^A = the slot number occupied by n-satellite;

H^A_n = the channel number of a carrier frequency of n^A-satellite (Table B-16);

λ^A_n = the longitude of the first (within the N^A-day) ascending node of n^A-satellite orbit in PZ-90 coordinate system;

$t_{\lambda}{}^A_n$ = the time of the first ascending node passage of n^A-satellite within N^A-day;

Table A-17. Ephemeris and time parameters

Parameter	Number of bits	Scale factor (LSB)	Effective range	Units
m	4	1		dimensionless
	5	1	0 to 23	hours
t_k	6	1	0 to 59	minutes
	1	30	0 or 30	seconds
t_b	7	15	15...1 425	minutes
$\gamma_n(t_b)$	11	2^{-40}	$\pm 2^{-30}$	dimensionless
$\tau_n(t_b)$	22	2^{-30}	$\pm 2^{-9}$	seconds
$x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$	27	2^{-11}	$\pm 2.7 \times 10^{4}$	km
$\dot{x}_n(t_b)$, $\dot{y}_n(t_b)$, $\dot{z}_n(t_b)$	24	2^{-20}	± 4.3	km/second
$\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$	5	2^{-30}	$\pm 6.2 \times 10^{-9}$	km/second^2
E_n	5	1	0 to 31	days
B_n	3	1	0 to 7	dimensionless
P1	2	———	as detailed in 3.2.1.3.1	———
P2	1	1	0; 1	dimensionless
P3	1	1	0; 1	dimensionless
$\Delta\tau_n$	5	2^{-30}	$\pm 13.97 \times 10^{-9}$	seconds

Table A-18. Arrangements of the ephemeris and time parameters within the frame

Parameter	Number of bits	String number within the frame	Bit number within the frame
m	4	1...15	81 – 84
t_k	12	1	65 – 76
t_b	7	2	70 – 76
$\gamma_n(t_b)$	11	3	69 – 79
$\tau_n(t_b)$	22	4	59 – 80
$x_n(t_b)$	27	1	9 – 35
$y_n(t_b)$	27	2	9 – 35
$z_n(t_b)$	27	3	9 – 35
$\dot{x}_n(t_b)$	24	1	41 – 64
$\dot{y}_n(t_b)$	24	2	41 – 64
$\dot{z}_n(t_b)$	24	3	41 – 64
$\ddot{x}_n(t_b)$	5	1	36 – 40
$\ddot{y}_n(t_b)$	5	2	36 – 40
$\ddot{z}_n(t_b)$	5	3	36 – 40
E_n	5	4	49 – 53
B_n	3	2	78 – 80
P1	2	1	77 – 78
P2	1	2	77
P3	1	3	80
$\Delta\tau_n$	5	4	54 – 58

Δi^A_n = the correction to the mean value of inclination of n^A-satellite at instant of $t_{\lambda}{}^A{}_n$ (mean value of inclination is equal to 63 degrees);

ΔT^A_n = the correction to the mean value of Draconian period of the n^A-satellite at the instant of $t_{\lambda}{}^A{}_n$ (mean value of Draconian period T is equal to 43 200 seconds);

$\Delta \dot{T}^A_n$ = the rate of change of Draconian period of n^A-satellite;

ε^A_n = the eccentricity of n^A-satellite at instant of $t_{\lambda}{}^A{}_n$;

ω^A_n = the argument of perigee of n^A-satellite at the instant of $t_{\lambda}{}^A{}_n$;

τ^A_n = the coarse value of n^A-satellite time correction to GLONASS time at instant of $t_{\lambda}{}^A{}_n$;

C^A_n = a generalized "unhealthy flag" of n^A-satellite at instant of almanac upload almanac of orbits and phases. When $C_n = 0$, this indicates that n-satellite is non-operational. When $C_n = 1$, this indicates that n-satellite is operational.

3.2.1.3.5 Partition and coding of almanac parameters. The GLONASS almanac, transmitted within the superframe, shall be partitioned over the superframe, as indicated in Table A-19. The numeric values of almanac parameters shall be positive or negative. The MSB shall be the sign bit, the chip "0" shall correspond to the "+" sign, and the chip "1" shall correspond to the "–" sign. The almanac parameters shall be coded as indicated in Table A-20.

3.2.1.3.6 Arrangement of the almanac parameters. Arrangement of the almanac words within the frame shall be as indicated in Table A-21.

3.2.1.4 Content and Structure of Additional Data Transmitted by Glonass-M Satellites

3.2.1.4.1 Letter designation of additional data. In addition to the GLONASS data, GLONASS-M satellites shall transmit the following additional data as indicated in Table A-17-A:

3.2.1.4.2 Additional data parameters. Additional data parameters are defined in Tables B-17-A to B-18-A.

3.2.1.4.3 Location of additional data words within GLONASS-M navigation message. The required location of additional data words within the GLONASS-M navigation message is defined in Table A-18-A.

n — an index of the satellite transmitting the given navigation signal: it corresponds to a slot number within GLONASS constellation;

l_n — health flag for n-th satellite: "0" indicates the n-th satellite is healthy, "1" indicates the malfunction of the n-th satellite;

B1 — coefficient to determine ΔUT1: it is equal to the difference between UT1 and UTC at the beginning of the day (N^A), expressed in seconds;

B2 — coefficient to determine ΔUT1: it is equal to the daily change of the difference ΔUT1 (expressed in seconds for a mean sun day).

These coefficients shall be used to transform between UTC(SU) and UT1:

$$\Delta UT1 = UTC(SU) - UT1,$$

where

UT1 — Universal Time referenced to the Mean Greenwich Meridian (taking account of Pole motion),

UTC(SU) — Coordinated Universal Time of the Russian Federation State Standard,

$$\Delta UT1 = B1 + B2 \times (N_T - N^A),$$

KP — notification of a forthcoming leap second correction of UTC (±1 s) as shown:

KP	UTC second correction data
00	No UTC correction at the end of the current quarter
01	UTC correction by plus 1 s at the end of the current quarter
11	UTC correction by minus 1 s at the end of the current quarter

Note.— GLONASS system timescale correction is usually performed once a year at midnight 00 hours 00 minutes 00 seconds in accordance with the early notification of the International Time Bureau (BIH/BIPM) at the end of a quarter:

from 31 December to 1 January — first quarter,
from 31 March to 1 April — second quarter,
from 30 June to 1 July — third quarter,
from 30 September to 1 October — fourth quarter.

N_T — current date, calendar number of the day within the four-year interval starting from 1 January in a leap year;

Note.— An example of N_T transformation into the common form of current data information (dd/mm/yy) is presented in Attachment D, 4.2.7.1.

N_4 — four-year interval number starting from 1996;

F_T — a parameter that provides the predicted satellite user range accuracy at time t_b. Coding is as indicated in Table B-17-B;

M — type of satellite transmitting the navigation signal. 00 refers to a GLONASS satellite; 01 refers to a GLONASS-M satellite;

P4 — flag to show that updated ephemeris parameters are present. "1" indicates that an updated ephemeris or frequency/time parameters have been uploaded by the control segment;

Note.— Updated ephemeris or frequency/time information is transmitted in the next interval after the end of the current interval t_b.

P — technological parameter of control segment indicating the satellite operation mode in respect of time parameters:

00 — τ_c parameter relayed from control segment, τ_{GPS} parameter relayed from control segment;

01 — τ_c parameter relayed from control segment, τ_{GPS} parameter calculated on-board the GLONASS-M satellite;

10 — τ_c parameter calculated on-board the GLONASS-M satellite; τ_{GPS} parameter relayed from control segment;

11 — τ_c parameter calculated on-board the GLONASS-M satellite; τ_{GPS} parameter calculated on-board the GLONASS-M satellite;

τ_{GPS} — correction to GPS time relative to GLONASS time:

$$T_{GPS} - T_{GL} = \Delta T + \tau_{GPS},$$

where

ΔT is the integer part, and τ_{GPS} is the fractional part of the difference between the system timescales expressed in seconds.

Note.— The integer part ΔT is determined from the GPS navigation message by the user receiver.

M^A_n — type of satellite n^A: coding "00" indicates a GLONASS satellite, coding "01" indicates a GLONASS-M satellite.

Table A-17-A. Additional data parameters

Parameter	No. of bits	Scale factor (LSB)	Effective range	Units
n	5	1	0 to 31	Dimensionless
l_n	1	1	0; 1	Dimensionless
B1	11	2^{-10}	±0.9	seconds
B2	10	2^{-16}	$(-4.5 \text{ to } 3.5) \times 10^{-3}$	s/mean sun day
KP	2	1	0 to 3	Dimensionless
N_T	11	1	0 to 1 461	days
N_4	5	1	1 to 31	four-year interval
F_T	4		See table B-17-B	
M	2	1	0 to 3	Dimensionless
P4	1	1	0; 1	Dimensionless
P	2	1	00,01,10,11	Dimensionless
τ_{GPS}	22	2^{-30}	$\pm 1.9 \times 10^{-3}$	seconds
M^A_n	2	1	0 to 3	Dimensionless

Table A-17-B. FT word coding

F_T value	Pseudorange accuracy, 1 sigma (m)
0	1
1	2
2	2.5
3	4
4	5
5	7
6	10
7	12
8	14
9	16
10	32
11	64
12	128
13	256
14	512
15	Not used

Table A-18-A. Location of additional data words within the GLONASS-M navigation message

Word	Number of bits	String number within the superframe	Bit number within the string
n	5	4, 19, 34, 49, 64	11 – 15
l_n	1	5, 7, 9, 11, 13, 15, 20, 22, 24, 26, 28, 30, 35, 37, 39, 41, 43, 45, 50, 52, 54, 56, 58, 60, 65, 67, 69, 71, 73, 75	9
		3, 18, 33, 48, 63	65
B1	11	74 (within the superframe)	70 – 80
B2	10	74 (within the superframe)	60 – 69
KP	2	74 (within the superframe)	58 – 59
N_T	11	4, 19, 34, 49, 64	16 – 26
N_4	5	5, 20, 35, 50, 65	32 – 36
F_T	4	4, 19, 34, 49, 64	30 – 33
M	2	4, 19, 34, 49, 64	9 – 10
P4	1	4, 19, 34, 49, 64	34
P	2	3, 18, 33, 48, 63	66 – 67
τ_{GPS}	22	5, 20, 35, 50, 65	10 – 31
$M^A{}_n$	2	6, 8, 10, 12, 14	78 – 79

Table A-19. Almanac partition within the superframe

Frame number within the superframe	Satellite numbers, for which almanac is transmitted within given frame
1	1 to 5
2	6 to 10
3	11 to 15
4	16 to 20
5	21 to 24

Table A-20. Almanac parameters coding

Parameters	Number of bits	Scale factor (LSB)	Effective range	Units
$M^A{}_n$	2	1	0 to 3	dimensionless
τ_c	28	2^{-27}	±1	seconds
N^A	11	1	1 to 1 461	days
n^A	5	1	1 to 24	dimensionless
$H^A{}_n$	5	1	0 to 31	dimensionless
$\lambda^A{}_n$	21	2^{-20}	±1	semi-circles
$t_\lambda{}^A{}_n$	21	2^{-5}	0 to 44 100	seconds
$\Delta i^A{}_n$	18	2^{-20}	±0.067	semi-circles
$\Delta T^A{}_n$	22	2^{-9}	$\pm 3.6 \times 10^3$	seconds/revolution
$\Delta \dot{T}^A{}_n$	7	2^{-14}	$\pm 2^{-8}$	seconds/revolution^2
$\varepsilon^A{}_n$	15	2^{-20}	0 to 0.03	dimensionless
$\omega^A{}_n$	16	2^{-15}	±1	semi-circles
$\tau^A{}_n$	10	2^{-18}	$\pm 1.9 \times 10^{-3}$	seconds
$C^A{}_n$	1	1	0 to 1	dimensionless

Table A-21. Arrangement of almanac parameters within the frame

Parameter	Number of bits	String number within the frame	Bit number within the string
M^A_n	2	6, 8, 10, 12, 14	78 – 79
τ_c	28	5	42 – 69
N^A	11	5	70 – 80
n^A	5	6, 8, 10, 12, 14	73 – 77
H^A_n	5	7, 9, 11, 13, 15	10 – 14
λ^A_n	21	6, 8, 10, 12, 14	42 – 62
$t_{\lambda}{}^A_n$	21	7, 9, 11, 13, 15	44 – 64
Δi^A_n	18	6, 8, 10, 12, 14	24 – 41
ΔT^A_n	22	7, 9, 11, 13, 15	22 – 43
$\Delta \dot{T}^A_n$	7	7, 9, 11, 13, 15	15 – 21
ε^A_n	15	6, 8, 10, 12, 14	9 – 23
ω^A_n	16	7, 9, 11, 13, 15	65 – 80
$t_{\tau}{}^A_n$	10	6, 8, 10, 12, 14	63 – 72
C^A_n	1	6, 8, 10, 12, 14	80

Note.— String numbers of the first four frames within superframe are given. There are no almanac parameters in 14th and 15th strings of 5th frame.

3.2.2 Definitions of Protocols for Data Application

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

Table B-22. Parity checking algorithm

b85, b84, ..., b10, b9 are the data bits (position 9 to 85 in the string);

β1, β2, ..., β8 are the check bits of the Hamming code (positions 1 to 8 in the string);

$c_1, c_2, \ldots, c_7, c_\Sigma$ are the checksums generated using the following:

$c_1 = \beta_1 \oplus [\Sigma_i b_i]_{mod\,2}$

i = 9, 10, 12, 13, 15, 17, 19, 20, 22, 24, 26, 28, 30, 32, 34, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84.

$c_2 = \beta_2 \oplus [\Sigma_j b_j]_{mod\,2}$

j = 9, 11, 12, 14, 15, 18, 19, 21, 22, 25, 26, 29, 30, 33, 34, 36, 37, 40, 41, 44, 45, 48, 49, 52, 53, 56, 57, 60, 61, 64, 65, 67, 68, 71, 72, 75, 76, 79, 80, 83, 84.

$c_3 = \beta_3 \oplus [\Sigma_k b_k]_{mod\,2}$

k = 10, 11, 12, 16, 17, 18, 19, 23, 24, 25, 26, 31, 32, 33, 34, 38, 39, 40, 41, 46, 47, 48, 49, 54, 55, 56, 57, 62, 63, 64, 65, 69, 70, 71, 72, 77, 78, 79, 80, 85.

$c_4 = \beta_4 \oplus [\Sigma_l b_l]_{mod\,2}$

l = 13, 14, 15, 16, 17, 18, 19, 27, 28, 29, 30, 31, 32, 33, 34, 42, 43, 44, 45, 46, 47, 48, 49, 58, 59, 60, 61, 62, 63, 64, 65, 73, 74, 75, 76, 77, 78, 79, 80.

$c_5 = \beta_5 \oplus [\Sigma_m b_m]_{mod\,2}$

m = 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 81, 82, 83, 84, 85.

$c_6 = \beta_6 \oplus [\Sigma_n b_n]_{mod\,2}$

n = 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65.

$c_7 = \beta_7 \oplus [\Sigma_p b_p]_{mod\,2}$

p = 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85.

$c_\Sigma = [\Sigma \beta_q]_{mod\,2} \oplus [\Sigma b_r]_{mod\,2}$

q = 1, 2, 3, 4, 5, 6, 7, 8

r = 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85.

3.2.2.1 Parity checking algorithm for data verification. The algorithm shown in Table A-22 and as detailed below is used to detect and correct an error of 1 bit within the string and to detect an error of 2 or more bits within a string.

3.2.2.1.1 Each string includes the 85 data bits where the 77 MSBs are data chips (b_{85}, b_{84}… b_{10}, b_9), and the 8 LSBs are the check bits of Hamming code length of 4 (β_8, β_7… β_2, β_1).

3.2.2.1.2 To correct 1-bit errors within the string the following checksums are generated: (c_1, c_2, …, c_7), and to detect 2-bit errors (or more-even-number-of-bits errors) a checksum c_Σ is generated, as shown in Table A-22. The following is used for correcting single errors and detecting multiple errors:

a) A string is considered correct if all checksums (c_1... c_7, and c_Σ) are equal to "0", or if only one of the checksums (c_1... c_7) is equal to "1" and c_Σ is equal to "1".

b) If two or more of the checksums (c_1, ..., c_7) are equal to "1" and c_Σ is equal to "1", then character "b_{icor}" is corrected to the opposite character in the following bit position:

"i_{cor}" = $c_7 c_6 c_5 c_4 c_3 c_2 c_1 + 8 - K$, provided that "$i_{cor}$" ≤ 85,
where "$c_7 c_6 c_5 c_4 c_3 c_2 c_1$" is a binary number generated from the checksums (c_1, ..., c_7) with c_1 being the LSB and c_7 being the MSB. K is the ordinal number of the most significant checksum not equal to "0".

If $i_{cor} > 85$, then there is an odd number of multiple errors, and the data shall be rejected.

c) If at least one of the checksums (c_1, ..., c_7) is equal to "1" and c_Σ is equal to "0", or if all checksums (c_1, ..., c_7) are equal to "0" but c_Σ is equal to "1", then there are multiple errors and the data shall be rejected.

3.2.2.2 Satellite Clock Correction Parameters

3.2.2.2.1 GLONASS system time is determined as:

$$t_{GLONASS} = t_k + \tau_n(t_b) - \gamma_n(t_b)\,(t_k - t_b)$$

where t_k, $\tau_n(t_b)$, $\gamma_n(t_b)$ are parameters described in 3.2.1.3.1.

3.2.2.2.2 GLONASS time is related to National Time Service of Russia (UTC(SU)) time as indicated below:

$$t_{UTC(SU)} = t_{GLONASS} + \tau_c - 03 \text{ hours } 00 \text{ minutes}$$

where

τ_c is a parameter described in 3.2.1.3.4 and

03 hours 00 minutes is continuous time shift caused by difference between Moscow time and Greenwich time.

3.2.2.3 Satellite Position

3.2.2.3.1 The current satellite position is defined using ephemeris parameters from GLONASS navigation, as indicated and in Table A-17.

3.2.2.3.2 Recalculation of ephemeris from instant t_b to instant t_i within the interval ($|\tau_i| = |t_i - t_b| \leq 15$ minutes) is performed using a technique of numeric integration of differential equations describing the motion of the satellites. In the right-hand parts of these equations the accelerations are determined using the gravitational constant μ and the second zonal harmonic of the geopotential J^2_0 which defines polar flattening of the earth, and accelerations due to luni-solar perturbation are taken into account. The equations are integrated in the PZ-90 (3.2.5) coordinate system by applying the Runge-Kutta technique of fourth order, as indicated below:

$$\frac{dx}{dt} = Vx$$

$$\frac{dy}{dt} = Vy$$

$$\frac{dz}{dt} = Vz$$

$$\frac{dV_x}{dt} = -\frac{\mu}{r^3}x - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}x\left(1-\frac{5z^2}{r^2}\right) + \omega^2 x + 2\omega V_y + \ddot{x}$$

$$\frac{dV_y}{dt} = -\frac{\mu}{r^3}y - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}y\left(1-\frac{5z^2}{r^2}\right) + \omega^2 y + 2\omega V_x + \ddot{y}$$

$$\frac{dV_z}{dt} = -\frac{\mu}{r^3}z - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}z\left(1-\frac{5z^2}{r^2}\right) + \ddot{z}$$

where

r = $\sqrt{x^2+y^2+z^2}$;
μ = earth's universal gravitational constant ($398\ 600.44 \times 10^9\ m^3/s^2$);
a_e = major semi-axis (6 378 136 m);
J^2_0 = second zonal harmonic of the geopotential ($1\ 082\ 625.7 \times 10^{-9}$); and
ω = earth's rotation rate (7.292115×10^{-5} radians/s).

Coordinates $x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$, and velocity vector components $\dot{x}_n(t_b) = V_x$, $\dot{y}_n(t_b) = V_y$, $\dot{z}_n(t_b) = V_z$ are initial conditions for the integration. Accelerations due to luni-solar perturbation $\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$ are constant on the integration interval ±15 minutes.

3.2.3 Aircraft Elements

3.2.3.1 GNSS (GLONASS) Receiver

3.2.3.1.1 Satellite exclusion. The receiver shall exclude any satellite designated unhealthy in the GLONASS navigation message.

3.2.3.1.2 Satellite tracking. The receiver shall provide the capability to continuously track a minimum of four satellites and generate a position solution based upon those measurements.

3.2.3.1.3 Doppler shift. The receiver shall be able to compensate for dynamic Doppler shift effects on nominal GLONASS signal carrier phase and standard code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.2.3.1.4 Resistance to interference. The receiver shall meet the requirements for resistance to interference as specified in regulation 173

3.2.3.1.4.1 Intrasystem interference. When receiving a navigation signal with frequency channel $k = n$, the interference created by a navigation signal with frequency channel number $k = n - 1$ or $k = n + 1$ shall not be more than –48 dBc with respect to the minimum specified satellite power at the surface of the earth provided that the satellites transmitting these signals are simultaneously located in user's visibility zone.

Note.— The intrasystem interference is the intercorrelation properties of the ranging pseudo-random signal with regard to frequency division multiple access.

3.2.3.1.5 Application of clock and ephemeris data. The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution.

3.2.3.1.6 Leap second correction. Upon GLONASS time leap second correction (see 3.2.1.3.1, t_b) the GLONASS receiver shall be capable of:

a) generating a smooth and valid series of pseudo-range measurements; and

b) resynchronizing the data string time mark without loss of signal tracking

3.2.3.1.6.1 After GLONASS time leap second correction the GLONASS receiver shall utilize the UTC time as follows:

a) utilize the old (prior to the correction) UTC time together with the old ephemeris (transmitted before 00 hours 00 minutes 00 seconds UTC); and

b) utilize the updated UTC time together with the new ephemeris (transmitted after 00 hours 00 minutes 00 seconds UTC).

3.2.4 Time

3.2.4.1 For the GLONASS-M satellites, the navigation message shall contain the data necessary to relate UTC(SU) time to UT1. GLONASS time shall be maintained to be within 1 millisecond of UTC(SU) time after correction for the integer number of hours due to GLONASS control segment specific features:

$$| t_{GLONASS} - (UTC + 03 \text{ hours } 00 \text{ minutes}) | < 1 \text{ ms}$$

The navigation data shall contain the requisite data to relate GLONASS time to UTC time (as maintained by the National Time Service of Russia, UTC (SU)) within 1 microsecond.

Note 1.— The timescales of GLONASS satellites are periodically compared with central synchronizer time. Corrections to the timescales of GLONASS satellites relative to GLONASS time and UTC(SU) time are computed at the GLONASS ground-based control complex and uploaded to the satellites twice per day.

Note 2.— There is no integer-second difference between GLONASS time and UTC time. The GLONASS timescale is periodically corrected to integer number of seconds simultaneously with UTC corrections which are performed according to the Bureau International de l'Heure notification (leap second correction). These corrections are performed at 00 hours 00 minutes 00 seconds UTC time at midnight at the end of a quarter of the year. Upon the GLONASS leap second correction the time mark within navigation message changes its position (in a continuous timescale) to become synchronized with 2-second epochs of corrected UTC timescale. GLONASS users are notified in advance on these planned corrections. For the GLONASS-M satellites, notification of these corrections is provided to users via the navigation message parameter KP.

3.2.4.2 Accuracy of mutual satellite timescales synchronization shall be 20 nanoseconds (1 sigma) for GLONASS satellites and 8 nanoseconds (1 sigma) for GLONASS-M satellites.

3.2.4.3 The correction to GPS time relative to GLONASS time (or difference between these timescales) broadcast by the GLONASS-M satellites, τ_{GPS}, shall not exceed 30 nanoseconds (1 sigma).

Note.— The accuracy of τ_{GPS} (30 ns) is determined with reference to the GPS SPS coarse acquisition signal and may be refined upon completion of trials of the GLONASS system using GLONASS-M satellites.

3.2.5 Coordinate System

3.2.5.1 PZ-90 (Parameters of common terrestrial ellipsoid and gravitational field of the earth

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.

3.4 Aircraft-based augmentation system (ABAS)

Note: Guidance on ABAS is given in ICAO Annex 10, Vol. I, Attachment C, section 5.

3.5 Satellite-based augmentation system (SBAS)

3.5.1 General

Note: Parameters in this section are defined in WGS-84.

3.5.2 RF Characteristics

3.5.2.1 Carrier frequency stability. The short-term stability of the carrier frequency (square root of the Allan Variance) at the output of the satellite transmit antenna shall be better than 5×10^{-11} over 1 to 10 seconds.

3.5.2.2 Carrier phase noise. The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

3.5.2.3 Spurious emissions. Spurious emissions shall be at least 40 dB below the unmodulated carrier power over all frequencies.

3.5.2.4 Code/carrier frequency coherence. The short-term (less than 10 seconds) fractional frequency difference between the code phase rate and the carrier frequency shall be less than 5×10^{-11} (standard deviation). Over the long term (less than 100 seconds), the difference between the change in the broadcast code phase, converted to carrier cycles by multiplying the number of code chips by 1 540, and the change in the broadcast carrier phase, in cycles, shall be within one carrier cycle (standard deviation).

Note. This applies to the output of the satellite transmit antenna and does not include code/carrier divergence due to ionospheric refraction in the downlink propagation path.

3.5.2.5 Correlation loss. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 1 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 2.046 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and a 2.046 MHz bandwidth.

3.5.2.6 Maximum code phase deviation. The maximum uncorrected code phase of the broadcast signal shall not deviate from the equivalent SBAS network time (SNT) by more than $\pm 2^{-20}$ seconds.

3.5.2.7 Code/data coherence. Each 2-millisecond symbol shall be synchronous with every other code epoch.

3.5.2.8 Message synchronization. The leading edge of the first symbol that depends on the first bit of the current message shall be broadcast from the SBAS satellite synchronous with a 1-second epoch of SNT.

3.5.2.9 Convolutional encoding. A 250-bit-per-second data stream shall be encoded at a rate of 2 symbols per bit using a convolutional code with a constraint length of 7 to yield 500 symbols per second. The convolutional encoder logic arrangement shall be as illustrated in Figure B-11 with the G3 output selected for the first half of each 4-millisecond data bit period.

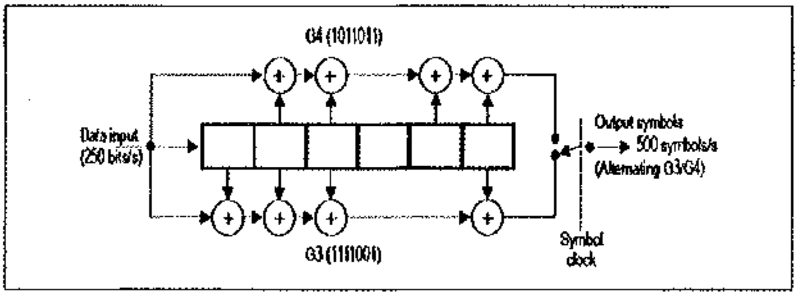

Figure B-11. Convolutional encoding

3.5.2.10 Pseudo-random noise (PRN) codes. Each PRN code shall be a 1 023-bit Gold code which is itself the Modulo-2 addition of two 1 023-bit linear patterns, G1 and $G2_i$. The $G2_i$ sequence shall be formed by delaying the G2 sequence by the associated integer number of chips as illustrated in Table A-23. Each of the G1 and G2 sequences shall be defined as the output of stage 10 of a 10-stage shift register, where the input to the shift register is the Modulo-2 addition of the following stages of the shift register:

a) G1: stages 3 and 10; and

b) G2: stages 2, 3, 6, 8, 9 and 10.

The initial state for the G1 and G2 shift registers shall be "1111111111".

Table A-23. SBAS PRN codes

120	145	110111001
121	175	101011110
122	52	1101001000
123	21	1101100101
124	237	1110000
125	235	111000001
126	886	1011
127	657	1000110000
128	634	10100101
129	762	101010111
130	355	1100011110
131	1 012	1010010110
132	176	1010101111
133	603	100110
134	130	1000111001
135	359	101110001
136	595	1000011111
137	68	111111000
138	386	1011010111

3.5.3 Data Structure

3.5.3.1 Format summary. All messages shall consist of a message type identifier, a preamble, a data field and a cyclic redundancy check as illustrated in Figure B-12.

3.5.3.2 Preamble. The preamble shall consist of the sequence of bits "01010011 10011010 11000110", distributed over three successive blocks. The start of every other 24-bit preamble shall be synchronous with a 6-second GPS subframe epoch.

3.5.3.3 Message type identifier. The message type identifier shall be a 6-bit value identifying the message type (Types 0 to 63) as defined in Table A-24. The message type identifier shall be transmitted MSB first.

3.5.3.4 Data field. The data field shall be 212 bits as defined in 3.5.6. Each data field parameter shall be transmitted MSB first.

3.5.3.5 Cyclic redundancy check (CRC). The SBAS message CRC code shall be calculated in accordance with 3.9.

3.5.3.5.1 The length of the CRC code shall be k = 24 bits.

3.5.3.5.2 The CRC generator polynomial shall be:

$$G(x) = x^{24} + x^{23} + x^{18} + x^{17} + x^{14} + x^{11} + x^{10} + x^{7} + x^{6} + x^{5} + x^{4} + x^{3} + x + 1$$

Table A-24. Broadcast message types

Message type	Contents
0	"Do Not Use" (SBAS test mode)
1	PRN mask
2 to 5	Fast corrections
6	Integrity information
7	Fast correction degradation factor
8	Spare
9	GEO ranging function parameters
10	Degradation parameters
11	Spare
12	SBAS network time/UTC offset parameters
13 to 16	Spare
17	GEO satellite almanacs
18	Ionospheric grid point masks
19 to 23	Spare
24	Mixed fast/long-term satellite error corrections
25	Long-term satellite error corrections
26	Ionospheric delay corrections
27	SBAS service message
28	Clock-ephemeris covariance matrix
29 to 61	Spare
62	Reserved
63	Null message

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

$$M(x) = \sum_{i=1}^{226} m_i x^{226-i} = m_1 x^{225} + m_2 x^{224} + \cdots + m_{226} x^0$$

3.5.3.5.4 M(x) shall be formed from the 8-bit SBAS message preamble, 6-bit message type identifier, and 212-bit data field. Bits shall be arranged in the order transmitted from the SBAS satellite, such that m_1 corresponds to the first transmitted bit of the preamble, and m_{226} corresponds to bit 212 of the data field.

3.5.3.5.5 The CRC code r-bits shall be ordered such that r_1 is the first bit transmitted and r_{24} is the last bit transmitted.

3.5.4 **Data Content**

3.5.4.1 PRN mask parameters. PRN mask parameters shall be as follows:

PRN code number: a number that uniquely identifies the satellite PRN code and related assignments as shown in Table A-25.

PRN mask: 210 PRN mask values that correspond to satellite PRN code numbers. The mask shall set up to 51 of the 210 PRN mask values.

Note.— The first transmitted bit of the PRN mask corresponds to PRN code number 1.

Table A-25. PRN code number assignments

PRN code number	Assignment
1 – 37	GPS
38 – 61	GLONASS slot number plus 37
62 – 119	Spare
120 – 138	SBAS
139 – 210	Spare

PRN mask value: a bit in the PRN mask indicating whether data are provided for the associated satellite PRN code number (1 to 210).

Coding: 0 = data not provided

1 = data provided

PRN mask number: the sequence number (1 to 51) of the mask values set in the PRN mask.

Note.— The PRN mask number is "1" for the lowest satellite PRN number for which the PRN mask value is "1".

Issue of data — PRN (IODP): an indicator that associates the correction data with a PRN mask.

Note.— Parameters are broadcast in the following messages:

a) PRN mask (consisting of 210 PRN mask values) in Type 1 message;

b) PRN mask number in Type 24, 25 and 28 messages;

c) PRN code number in Type 17 message; and

d) IODP in Type 1 to 5, 7, 24, 25 and 28 messages.

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

$t_{0,GEO}$: the reference time for the GEO ranging function data, expressed as the time after midnight of the current day.

$[X_G Y_G Z_G]$: the position of the GEO at time $t_{0,GEO}$.

$[\dot{X}_G \dot{Y}_G \dot{Z}_G]$: the velocity of the GEO at time $t_{0,GEO}$.

$[\ddot{X}_G \ddot{Y}_G \ddot{Z}_G]$: the acceleration of the GEO at time $t_{0,GEO}$.

a_{Gf0}: the time offset of the GEO clock with respect to SNT, defined at $t_{0,GEO}$.

a_{Gf1}: the drift rate of the GEO clock with respect to SNT.

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

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

Table A-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).

3.5.4.3 GEO almanac parameters. GEO almanac parameters shall be as follows:

PRN code number: see 3.5.4.1

Health and status: an indication of the functions provided by the SBAS. The service provider identifiers are shown in Table A-27.

Coding:	Bit 0 (LSB)	Ranging	On (0)	Off (1)
	Bit 1	Precision corrections	On (0)	Off (1)
	Bit 2	Satellite status and basic corrections	On (0)	Off (1)
	Bits 3	Spare		
	Bits 4 to 7	Service provider identifier		

Note.— A service provider ID of 14 is used for GBAS and is not applicable to SBAS.

$[X_{G,A} Y_{G,A} Z_{G,A}]$: the position of the GEO at time $t_{almanac}$.

$[\dot{X}_{G,A} \dot{Y}_{G,A} \dot{Z}_{G,A}]$: the velocity of the GEO at time $t_{almanac}$.

$t_{almanac}$: the reference time for the GEO almanac data, expressed as the time after midnight of the current day.

Note.— All parameters are broadcast in Type 17 message.

3.5.4.4 Satellite Correction Broadcast Parameters

3.5.4.4.1 Long-term correction parameters shall be as follows:

Issue of data (IOD_i): an indicator that associates the long-term corrections for the i^{th} satellite with the ephemeris data broadcast by that satellite.

Note 1.— For GPS, the IOD_i matches the IODE and 8 LSBs of the IODC (3.1.1.3.1.4 and 3.1.1.3.2.2).

Note 2.— For GLONASS, the IOD_i indicates a period of time that GLONASS data are to be used with SBAS data. It consists of two fields as shown in Table A-28.

δx_i: for satellite i, the ephemeris correction for the x axis.

δy_i: for satellite i, the ephemeris correction for the y axis.

δz_i: for satellite i, the ephemeris correction for the z axis.

$\delta a_{i,f0}$: for satellite i, the ephemeris time correction.

$\delta x'_i$: for satellite i, ephemeris velocity correction for x axis

$\delta y'_i$: for satellite i, ephemeris velocity correction for y axis.

$\delta z'_i$: for satellite i, ephemeris velocity correction for z axis.

$\delta a_{i,f1}$: for satellite i, rate of change of the ephemeris time correction.

$t_{i,LT}$: the time of applicability of the parameters δx_i, δy_i, δz_i, $\delta a_{i,f0}$, $\delta x'_i$, $\delta y'_i$, $\delta z'_i$ and $\delta a_{i,f1}$, expressed in seconds after midnight of the current day.

Velocity code: an indicator of the message format broadcast (Table A-48 and

Table A-49).

Coding: $0 = \delta x'_i$, $\delta y'_i$, $\delta z'_i$ and $\delta a_{i,f1}$ are not broadcast.

$1 = \delta x'_i$, $\delta y'_i$, $\delta z'_i$ and $\delta a_{i,f1}$ are broadcast.

Note.— All parameters are broadcast in Type 24 and 25 messages.

Table A-27. SBAS service provider identifiers

Identifier	Service provider
0	WAAS
1	EGNOS
2	MSAS
3	GAGAN
4	SDCM
5 to 13	Spare
14, 15	Reserved

Table A-28. IOD_i for GLONASS satellites

MSB	LSB
Validity interval (5 bits)	Latency time (3 bits)

3.5.4.4.2 Fast correction parameters shall be as follows:

Fast correction (FC_i): for satellite i, the pseudo-range correction for rapidly varying errors, other than tropospheric or ionospheric errors, to be added to the pseudo-range after application of the long-term correction.

Note.— The user receiver applies separate tropospheric corrections (3.5.8.4.2 and 3.5.8.4.3).

Fast correction type identifier: an indicator (0, 1, 2, 3) of whether the Type 24 message contains the fast correction and integrity data associated with the PRN mask numbers from Type 2, Type 3, Type 4 or Type 5 messages, respectively.

Issue of data-fast correction ($IODF_j$): an indicator that associates $UDREI_i$s with fast corrections. The index j shall denote the message type (j = 2 to 5) to which $IODF_j$ applies (the fast correction type identifier +2).

Note.— The fast correction type identifier is broadcast in Type 24 messages. The FC_i are broadcast in Type 2 to 5, and Type 24 messages. The $IODF_j$ are broadcast in Type 2 to 6, and Type 24 messages.

3.5.4.5 Fast and long-term correction integrity parameters. Fast and long-term correction integrity parameters shall be as follows:

$UDREI_i$: an indicator that defines the $\sigma^2_{i,UDRE}$ for satellite i as described in Table A-29.

Model variance of residual clock and ephemeris errors ($\sigma^2_{i,UDRE}$): the variance of a normal distribution associated with the user differential range errors for satellite i after application of fast and long-term corrections, excluding atmospheric effects and used in horizontal protection level/vertical protection level computations (3.5.5.6).

Note.— All parameters are broadcast in Type 2 to 6, and Type 24 messages.

3.5.4.6 Ionospheric correction parameters. Ionospheric correction parameters shall be as follows:

IGP mask: a set of 11 ionospheric grid point (IGP) band masks defined in Table A-30.

IGP band mask: a set of IGP mask values which correspond to all IGP locations in one of the 11 IGP bands defined in Table A-30.

Table A-29. Evaluation of $UDREI_i$

$UDREI_i$	$\sigma^2_{i,UDRE}$
0	0.0520 m²
1	0.0924 m²
2	0.1444 m²
3	0.2830 m²
4	0.4678 m²
5	0.8315 m²
6	1.2992 m²
7	1.8709 m²
8	2.5465 m²
9	3.3260 m²
10	5.1968 m²
11	20.7870 m²
12	230.9661 m²
13	2 078.695 m²
14	"Not Monitored"
15	"Do Not Use"

IGP mask value: a bit indicating whether data are provided within that IGP band for the associated IGP.

Coding: 0 = data are not provided
1 = data are provided

Number of IGP bands: the number of IGP band masks being broadcast.

IGP band identifier: the number identifying the ionospheric band as defined in Table B-30.

IGP block identifier: the identifier of the IGP block. The IGP blocks are defined by dividing into groups of 15 IGPs the sequence of IGPs within an IGP band mask which have IGP mask values of "1". The IGP blocks are numbered in an order of IGP mask value transmission, starting with "0".

Validity interval (V): the time interval for which the GLONASS ephemeris data are applicable (coded with an offset of 30 s) as described in Table B-31.

Latency time (L): the time interval between the time the last GLONASS ephemeris has been received by the ground segment and the time of transmission of the first bit of the long-term correction message at the GEO(t_{ltc}) as described in Table B-32.

$IODI_k$: an indication of when the k^{th} IGP band mask changes.

IGP vertical delay estimate: an estimate of the delay induced for a signal at 1 575.42 MHz if it traversed the ionosphere vertically at the IGP.

Coding: The bit pattern "111111111" indicates "Do Not Use".

$GIVEI_i$: an indicator that defines the $\sigma^2_{i,GIVE}$ as described in Table B-33.

Model variance of residual ionospheric errors ($\sigma^2_{i,GIVE}$): the variance of a normal distribution associated with the residual ionospheric vertical error at the IGP for an L1 signal.

Note.— All parameters are broadcast in Type 18 and Type 26 messages.

IGP location		Transmission order in IGP band mask
Band 0		
180 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	1 – 28
175 W	55S, 50S, 45S, ..., 45N, 50N, 55N	29 – 51
170 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	52 – 78
165 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
160 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
155 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
150 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
145 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 1		
140 W	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 28

IGP location		Transmission order in IGP band mask
135 W	55S, 50S, 45S, ..., 45N, 50N, 55N	29 – 51
130 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	52 – 78
125 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
120 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
115 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
110 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
105 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 2		
100 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
95 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
90 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	51 – 78
85 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
80 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
75 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
70 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
65 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 3		
60 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
55 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
50 W	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 78
45 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
40 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
35 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
30 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
25 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 4		
20 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
15 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
10 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
5 W	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
0	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	101 – 128
5 E	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
10 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
15 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 5		
20 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
25 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50

IGP location		Transmission order in IGP band mask
30 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
35 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
40 E	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 128
45 E	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
50 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
55 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 6		
60 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
65 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
70 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
75 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
80 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
85 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
90 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	151 – 178
95 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 7		
100 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
105 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
110 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
115 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
120 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
125 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
130 E	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	151 – 178
135 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 8		
140 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
145 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
150 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
155 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
160 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
165 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
170 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	151 – 177
175 E	55S, 50S, 45S, ..., 45N, 50N, 55N	178 – 200
Band 9		
60 N	180W, 175W, 170W, ..., 165E, 170E, 175E	1 – 72
65 N	180W, 170W, 160W, ..., 150E, 160E, 170E	73 – 108
70 N	180W, 170W, 160W, ..., 150E, 160E, 170E	109 – 144

IGP location		Transmission order in IGP band mask
75 N	180W, 170W, 160W, ..., 150E, 160E, 170E	145 – 180
85 N	180W, 150W, 120W, ..., 90E, 120E, 150E	181 – 192
Band 10		
60 S	180W, 175W, 170W, ..., 165E, 170E, 175E	1 – 72
65 S	180W, 170W, 160W, ..., 150E, 160E, 170E	73 – 108
70 S	180W, 170W, 160W, ..., 150E, 160E, 170E	109 – 144
75 S	180W, 170W, 160W, ..., 150E, 160E, 170E	145 – 180
85 S	170W, 140W, 110W, ..., 100E, 130E, 160E	181 – 192

Table A-31. Validity interval

Data	Bits used	Range of values	Resolution
Validity interval (V)	5	30 s to 960 s	30 s

Table A-32. Latency time

Data	Bits used	Range of values	Resolution
Latency time (L)	3	0 s to 120 s	30 s

Table A-33. Evaluation of GIVEIi

$GIVEI_i$	$\sigma^2_{i,GIVE}$
0	0.0084 m^2
1	0.0333 m^2
2	0.0749 m^2
3	0.1331 m^2
4	0.2079 m^2
5	0.2994 m^2
6	0.4075 m^2
7	0.5322 m^2
8	0.6735 m^2
9	0.8315 m^2
10	1.1974 m^2
11	1.8709 m^2
12	3.3260 m^2
13	20.787 m^2
14	187.0826 m^2
15	"Not Monitored"

3.5.4.7 Degradation parameters. Degradation parameters, whenever used, shall be as follows:

Fast correction degradation factor indicator (ai_i): an indicator of the fast correction degradation factor (a_i) for the i^{th} satellite as described in Table A-34.

Note. — The ai_i is also used to define the time-out interval for fast corrections, as described in 3.5.8.1.2.

System latency time (t_{lat}): the time interval between the origin of the fast correction degradation and the user differential range estimate indicator (UDREI) reference time.

B_{rrc}: a parameter that bounds the noise and round-off errors when computing the range rate correction degradation as in 3.5.5.6.2.2.

C_{ltc_lsb}: the maximum round-off error due to the resolution of the orbit and clock information.

C_{ltc_v1}: the velocity error bound on the maximum range rate difference of missed messages due to clock and orbit rate differences.

I_{ltc_v1}: the update interval for long-term corrections if velocity code = 1 (3.5.4.4.1).

C_{ltc_v0}: a parameter that bounds the difference between two consecutive long-term corrections for satellites with a velocity code = 0.

I_{ltc_v0}: the minimum update interval for long-term messages if velocity code = 0 (3.5.4.4.1).

C_{geo_lsb}: the maximum round-off error due to the resolution of the orbit and clock information.

C_{geo_v}: the velocity error bound on the maximum range rate difference of missed messages due to clock and orbit rate differences.

I_{geo}: the update interval for GEO ranging function messages.

Table A-34. Fast correction degradation factor

Fast correction degradation factor indicator (ai_i)	Fast correction degradation factor (a_i)
0	0.0 mm/s²
1	0.05 mm/s²
2	0.09 mm/s²
3	0.12 mm/s²
4	0.15 mm/s²
5	0.20 mm/s²
6	0.30 mm/s²
7	0.45 mm/s²
8	0.60 mm/s²
9	0.90 mm/s²
10	1.50 mm/s²
11	2.10 mm/s²
12	2.70 mm/s²
13	3.30 mm/s²
14	4.60 mm/s²
15	5.80 mm/s²

C_{er}: the bound on the residual error associated with using data beyond the precision approach/approach with vertical guidance time-out.

C_{iono_step}: the bound on the difference between successive ionospheric grid delay values.

I_{iono}: the minimum update interval for ionospheric correction messages.

$C_{iono\ ramp}$: the rate of change of the ionospheric corrections.

RSS_{UDRE}: the root-sum-square flag for fast and long-term correction residuals.

Coding: 0 = correction residuals are linearly summed
1 = correction residuals are root-sum-squared

RSS_{iono}: the root-sum-square flag for ionospheric residuals.

Coding: 0 = correction residuals are linearly summed
1 = correction residuals are root-sum-squared

$C_{covariance}$: the term which is used to compensate for quantization effects when using the Type 28 message.

Note 1.— The parameters a_i and t_{lat} are broadcast in Type 7 message. All other parameters are broadcast in Type 10 message.

Note 2.— If message Type 28 is not broadcast, $C_{covariance}$ is not applicable.

3.5.4.8 Time parameters. Time parameters, whenever used, shall be as follows:

UTC standard identifier: an indication of the UTC reference source as defined in Table A-35.

GPS time-of-week count: the number of seconds that have passed since the transition from the previous GPS week (similar to the GPS parameter in 3.1.1.2.6.1 but with a 1-second resolution).

Table A-35. UTC standard identifier

UTC standard identifier	UTC standard
0	UTC as operated by the Communications Research Laboratory, Tokyo, Japan
1	UTC as operated by the U.S. National Institute of Standards and Technology
2	UTC as operated by the U.S. Naval Observatory
3	UTC as operated by the International Bureau of Weights and Measures
4	Reserved for UTC as operated by a European laboratory
5 to 6	Spare
7	UTC not provided

GPS week number (week count): see 3.1.1.2.6.2.

GLONASS indicator: a flag indicating if GLONASS time parameters are provided.

Coding: 0 = GLONASS time parameters are not provided
1 = GLONASS time parameters are provided

GLONASS time offset ($\delta a_{i,GLONASS}$): A parameter that represents the stable part of the offset between the GLONASS time and the SBAS network time.

Note.— If SBAS does not support GLONASS, $\delta a_{i,GLONASS}$ is not applicable.

UTC parameters: A_{1SNT}, A_{0SNT}, t_{ot}, WN_t, Δt_{LS}, WN_{LSF}, DN and Δt_{LSF} are as described in 3.1.1.3.3.6, with the exception that the SBAS parameters relate SNT to UTC time, rather than GPS time.

Note.— All parameters are broadcast in Type 12 message

3.5.4.9 Service region parameters. Service region parameters shall be as follows:

Issue of data, service (IODS): an indication of a change of the service provided in the region.

Number of service messages: the number of different Type 27 SBAS service messages being broadcast. (Value is coded with an offset of 1.)

Service message number: a sequential number identifying the message within the currently broadcast set of Type 27 messages (from 1 to number of service messages, coded with an offset of 1).

Number of regions: the number of service regions for which coordinates are broadcast in the message.

Priority code: an indication of a message precedence if two messages define overlapping regions. The message with a higher value of priority code takes precedence. If priority codes are equal, the message with the lower δUDRE takes precedence.

δUDRE indicator-inside: an indication of regional UDRE degradation factor (δUDRE) applicable at locations inside any region defined in the message, in accordance with Table B-36.

δUDRE indicator-outside: an indication of regional UDRE degradation factor (δUDRE) applicable at locations outside all regions defined in all current Type 27 messages, in accordance with Table B-36.

Coordinate latitude: the latitude of one corner of a region.

Coordinate longitude: the longitude of one corner of a region.

Region shape: an indication of whether a region is a triangle or quadrangle.

Coding: 0 = triangle
1 = quadrangle

Note 1.— Coordinate 3 has Coordinate 1 latitude and Coordinate 2 longitude. If region is a quadrangle, Coordinate 4 has Coordinate 2 latitude and Coordinate 1 longitude. Region boundary is formed by joining coordinates in the sequence 1-2-3-1 (triangle) or 1-3-2-4-1 (quadrangle). Boundary segments have either constant latitude, constant longitude, or constant slope in degrees of latitude per degree of longitude. The change in latitude or longitude along any boundary segment between two coordinates is less than ±180 degrees.

Table A-36. δUDRE indicator evaluation

δUDRE indicator	δUDRE
0	1
1	1.1
2	1.25
3	1.5
4	2
5	3
6	4
7	5
8	6
9	8
10	10
11	20
12	30
13	40
14	50
15	100

3.5.4.10 Clock-ephemeris covariance matrix parameters. Clock-ephemeris covariance matrix parameters shall be as follows:

PRN mask number: see 3.5.4.1.

Scale exponent: A term to compute the scale factor used to code the Cholesky factorization elements.

Cholesky factorization elements ($E_{i,j}$): Elements of an upper triangle matrix which compresses the information in the clock and ephemeris covariance matrix. These elements are used to compute the user differential range estimate (UDRE) degradation factor (δUDRE) as a function of user position.

3.5.5 Definitions of Protocols for Data Application

Note.— This section provides definitions of parameters used by the non-aircraft or aircraft elements that are not transmitted. These parameters, necessary to ensure interoperability of SBAS, are used to determine the navigation solution and its integrity (protection levels).

3.5.5.1 Geo Position and Clock

3.5.5.1.1 GEO position estimate. The estimated position of a GEO at any time t_k is:

$$\begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} = \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} + \begin{bmatrix} \dot{X}_G \\ \dot{Y}_G \\ \dot{Z}_G \end{bmatrix} (t - t_{0,GEO}) + \frac{1}{2} \begin{bmatrix} \ddot{X}_G \\ \ddot{Y}_G \\ \ddot{Z}_G \end{bmatrix} (t - t_{0,GEO})^2$$

3.5.5.1.2 GEO clock correction. The clock correction for a SBAS GEO satellite i is applied in accordance with the following equation:

$$t = t_G - \Delta t_G$$

where

t = SBAS network time;

t_G = GEO code phase time at transmission of message; and

Δt_G = GEO code phase offset.

3.5.5.1.2.1 GEO code phase offset (Δt_G) at any time t is:

$$\Delta t_G = a_{Gf0} + a_{Gf1} (t - t_{0,GEO})$$

where $(t - t_{0,GEO})$ is corrected for end-of-day crossover.

3.5.5.2 Long-Term Corrections

3.5.5.2.1 GPS clock correction. The clock correction for a GPS satellite i is applied in accordance with the following equation:

$$t = t_{SV,i} - [(\Delta t_{SV,i})_{L1} + \delta\Delta t_{SV,i}]$$

where

t	=	SBAS network time;
$t_{SV,i}$	=	the GPS satellite time at transmission of message;
$(\Delta t_{SV,i})_{L1}$	=	the satellite PRN code phase offset as defined in 3.1.2.2; and
$\delta\Delta t_{SV,i}$	=	the code phase offset correction.

3.5.5.2.1.1 The code phase offset correction ($\delta\Delta t_{SV,i}$) for a GPS or SBAS satellite i at any time of day t_k is:

$$\delta\Delta t_{SV,i} = \delta a_{i,f0} + \delta a_{i,f1} (t_k - t_{i,LT})$$

3.5.5.2.2 GLONASS clock correction. The clock correction for a GLONASS satellite i is applied in accordance with the following equation:

$$t = t_{SV,i} + \tau_n(t_b) - \gamma_n(t_b)(t_{SV,i} - t_b) - \delta\Delta t_{SV,i}$$

where

t	=	SBAS network
$t_{SV,i}$	=	the GLONASS satellite time at transmission of message
t_b, $\tau_n(t_b)$, $\gamma_n(t_b)$	=	the GLONASS time parameters as defined in 3.2.2.2
$\delta\Delta t_{SV,i}$	=	the code phase offset correction

The code phase offset correction $\delta\Delta t_{SV,i}$ for a GLONASS satellite i is:

$$\delta\Delta t_{SV,i} = \delta a_{i,f0} + \delta a_{i,f1}(t - t_{i,LT}) + \delta a_{i,GLONASS}$$

where $(t - t_{i,LT})$ is corrected for end-of-day crossover. If the velocity code = 0, then $\delta a_{i,f1} = 0$.

3.5.5.2.3 Satellite position correction. The SBAS-corrected vector for a core satellite constellation(s) or SBAS satellite i at time t is:

$$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}_{corrected} = \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} + \begin{bmatrix} \delta x_i \\ \delta y_i \\ \delta z_i \end{bmatrix} + \begin{bmatrix} \delta \dot{x}_i \\ \delta \dot{y}_i \\ \delta \dot{z}_i \end{bmatrix} (t - t_{i,LT})$$

where

$(t - t_{i,LT})$ is corrected for end-of-day crossover; and
$[x_i\ y_i\ z_i]^T$ = the core satellite constellation(s) or SBAS satellite position vector as defined in 3.1.2.3, 3.2.2.3 and 3.5.5.1.1.

If the velocity code = 0, then $[\delta\dot{x}_i\ \delta\dot{y}_i\ \delta\dot{z}_i]^T = [0\ \ 0\ \ 0]^T$.

3.5.5.3 Pseudo-range corrections. The corrected pseudo-range at time t for satellite i is:

$$PR_{i,corrected} = PR_i + FC_i + RRC_i\,(t - t_{i,of}) + IC_i + TC_i$$

where

PR_i	=	the measured pseudo-range after application of the satellite clock correction;
FC_i	=	the fast correction;
RRC_i	=	the range rate correction;
IC_i	=	the ionospheric correction;
TC_i	=	the tropospheric correction (negative value representing the troposphere delay); and
$t_{i,of}$	=	the time of applicability of the most recent fast corrections, which is the start of the epoch of the SNT second that is coincident with the transmission at the SBAS satellite of the first symbol of the message block.

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

$$\mathrm{RRC}_i = \begin{cases} \dfrac{FC_{i,current} - FC_{i,previous}}{t_{i,of} - t_{i,of\_previous}}, if\ a_i \neq 0 \\ 0, if\ a_i = 0 \end{cases}$$

where

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

3.5.5.5 Broadcast Ionospheric Corrections

3.5.5.5.1 Location of ionospheric pierce point (IPP). The location of an IPP is defined to be the intersection of the line segment from the receiver to the satellite and an ellipsoid with constant height of 350 km above the WGS-84 ellipsoid. This location is defined in WGS-84 latitude (φ_{pp}) and longitude (λ_{pp}).

3.5.5.5.2 Ionospheric corrections. The ionospheric correction for satellite i is:

$$IC_i = -F_{pp}\,\tau_{vpp}$$

where

F_{pp} = obliquity factor $= \left[1 - \left(\frac{R_e \cos\theta_i}{R_e + h_I}\right)^2\right]^{-\frac{1}{2}}$;
τ_{vpp} = interpolated vertical ionospheric delay estimate (3.5.5.5.3);
R_e = 6 378.1363 km;
θ_i = elevation angle of satellite *i*; and
h_I = 350 km.

Note.— For GLONASS satellites, the ionospheric correction (IC_i) is to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies $(f_{GLONASS}/f_{GPS})^2$.

3.5.5.5.3 Interpolated vertical ionospheric delay estimate. When four points are used for interpolation, the interpolated vertical ionospheric delay estimate at latitude φ_{pp} and longitude λ_{pp} is:

$$\tau_{vpp} = \sum_{k=1}^{4} W_k \tau_{vk}$$

where

τ_{vk}: the broadcast grid point vertical delay values at the k^{th} corner of the IGP grid, as shown in Figure B-13.

$W_1 = x_{pp}\, y_{pp}$;
$W_2 = (1 - x_{pp})\, y_{pp}$;
$W_3 = (1 - x_{pp})\,(1 - y_{pp})$; and
$W_4 = x_{pp}\,(1 - y_{pp})$.

3.5.5.5.3.1 For IPPs between N85° and S85°:

$$x_{pp} = \frac{\lambda_{pp} - \lambda_1}{\lambda_2 - \lambda_1}$$

$$y_{pp} = \frac{\phi_{pp} - \phi_1}{\phi_2 - \phi_1}$$

where

λ_1 = longitude of IGPs west of IPP;
λ_2 = longitude of IGPs east of IPP;
ϕ_1 = latitude of IGPs south of IPP; and
ϕ_2 = latitude of IGPs north of IPP.

Note.— If λ_1 and λ_2 cross 180 degrees of longitude, the calculation of x_{pp} must account for the discontinuity in longitude values.

3.5.5.5.3.2 For IPPs north of N85° or south of S85°:

$$y_{pp} = \frac{|\phi_{pp}| - 85°}{10°}$$

$$x_{pp} = \frac{\lambda_{pp} - \lambda_3}{90°} \times (1 - 2\,y_{pp}) + y_{pp}$$

where

λ_1 = longitude of the second IGP to the east of the IPP;
λ_2 = longitude of the second IGP to the west of the IPP;
λ_3 = longitude of the closest IGP to the west of the IPP; and
λ_4 = longitude of the closest IGP to the east of the IPP.

When three points are used for interpolation, the interpolated vertical ionospheric delay estimated is:

3.5.5.5.3.3 For points between S75° and N75°:

$$\tau_{vpp} = \sum_{k=1}^{3} W_k \tau_{vk}$$

where

$W_1 = y_{pp}$;
$W_2 = 1 - x_{pp} - y_{pp}$; and
$W_3 = x_{pp}$.

3.5.5.5.3.4 x_{pp} and y_{pp} are calculated as for four-point interpolation, except that λ_1 and φ_1 are always the longitude and latitude of IGP2, and λ_2 and φ_2 are the other longitude and latitude. IGP2 is always the vertex opposite the hypotenuse of the triangle defined by the three points, IGP1 has the same longitude as IGP2, and IGP3 has the same latitude as IGP2 (an example is shown in Figure B-14).

3.5.5.5.3.5 For points north of N75° and south of S75°, three-point interpolation is not supported.

3.5.5.5.4 Selection of ionospheric grid points (IGPs). The protocol for the selection of IGPs is:

a) For an IPP between N60° and S60°:

1) if four IGPs that define a 5-degree-by-5-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

2) if any three IGPs that define a 5-degree-by-5-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

3) if any four IGPs that define a 10-degree-by-10-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

4) if any three IGPs that define a 10-degree-by-10-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

5) an ionospheric correction is not available.;

b) For an IPP between N60° and N75° or between S60° and S75°:

1) if four IGPs that define a 5-degree-latitude-by-10-degree longitude cell around the IPP are set to "1" in the IGP mask, they are selected; else,

2) if any three IGPs that define a 5-degree-latitude-by-10-degree longitude triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

3) if any four IGPs that define a 10-degree-by-10-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

4) if any three IGPs that define a 10-degree-by-10-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

5) an ionospheric correction is not available;

c) For an IPP between N75° and N85° or between S75° and S85°:

1) if the two nearest IGPs at 75° and the two nearest IGPs at 85° (separated by 30° longitude if Band 9 or 10 is used, separated by 90° otherwise) are set to "1" in the IGP mask, a 10-degree-by-10-degree cell is created by linearly interpolating between the IGPs at 85° to obtain virtual IGPs at longitudes equal to the longitudes of the IGPs at 75°; else,

2) an ionospheric correction is not available;

d) For an IPP north of N85°

1) if the four IGPs at N85° latitude and longitudes of W180°, W90°, 0° and E90° are set to "1" in the IGP mask, they are selected; else,

2) an ionospheric correction is not available; and

e) For an IPP south of S85°:

1) if the four IGPs at S85° latitude and longitudes of W140°, W50°, E40° and E130° are set to "1" in the IGP mask, they are selected; else,

2) an ionospheric correction is not available.

Note.— This selection is based only on the information provided in the mask, without regard to whether the selected IGPs are monitored, "Not Monitored", or "Do

Not Use". If any of the selected IGPs is identified as "Do Not Use", an ionospheric correction is not available. If four IGPs are selected, and one of the four is identified as "Not Monitored", then three-point interpolation is used if the IPP is within the triangular region covered by the three corrections that are provided.

3.5.5.6 Protection levels. The horizontal protection level (HPL) and the vertical protection level (VPL) are:

$$HPL_{SBAS} = \begin{cases} K_{H,NPA} \times d_{major} & \text{for en-route through non-precision approach (NPA) modes} \\ K_{H,PA} \times d_{major} & \text{for precision approach (PA) and approach with vertical guidance (APV) modes} \end{cases}$$

$$VPL_{SBAS} = K_{V,PA} \times d_V$$

where

$d_V^2 = \sum_{i=1}^{N} s_{V,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the vertical axis;

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

where

$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the x axis;

$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the y axis;

$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$ = covariance of model distribution in the x and y axis;

where

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

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

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

$\sigma_i^2 = \sigma_{i,flt}^2 + \sigma_{i,UIRE}^2 + \sigma_{i,air}^2 + \sigma_{i,tropo}^2$

The variances ($\sigma_{i,flt}^2$ and $\sigma_{i,UIRE}^2$) are defined in 3.5.5.6.2 and 3.5.5.6.3.1. The parameters ($\sigma_{i,air}^2$ and $\sigma_{i,tropo}^2$) are determined by the aircraft element (3.5.8.4.2 and 3.5.8.4.3).

The x and y axes are defined to be in the local horizontal plane, and the v axis represents local vertical.

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

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

where

$G_i = [-\cos El_i \cos Az_i \; -\cos El_i \sin Az_i \; -\sin El_i \; 1] = i^{th}$ row of G;

$$W^{-1} = \begin{bmatrix} w_1 & 0 & \dots & 0 \\ 0 & w_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & & \dots & w_i \end{bmatrix};$$

El_i = the elevation angle of the i^{th} ranging source (in degrees);
Az_i = the azimuth of the i^{th} ranging source taken counter-clockwise from the x axis in degrees; and
w_i = the inverse weight associated with satellite $i = \sigma_i^2$.

Note 1.— To improve readability, the subscript i was omitted from the projection matrix's equation.

Note 2.— For an unweighted least-squares solution, the weighting matrix is an identity matrix ($w_i = 1$).

3.5.5.6.1 Definition of K values. The K values are:

$$K_{H,NPA} = 6.18;$$

$$K_{H,PA} = 6.0; \text{ and}$$

$$K_{V,PA} = 5.33.$$

3.5.5.6.2 Definition of fast and long-term correction error model. If fast corrections and long-term correction/GEO ranging parameters are applied, and degradation parameters are applied:

$$\sigma_{i,flt}^2 = \begin{cases} \left[(\sigma_{i,UDRE})(\delta_{UDRE}) + \varepsilon_{fc} + \varepsilon_{rrc} + \varepsilon_{ltc} + \varepsilon_{er}\right]^2, & \text{if } RSS_{UDRE} = 0 \text{ (Message Type 10)} \\ \left[(\sigma_{i,UDRE})(\delta_{UDRE})\right]^2 + \varepsilon^2_{fc} + \varepsilon^2_{rrc} + \varepsilon^2_{ltc} + \varepsilon^2_{er}, & \text{if } RSS_{UDRE} = 1 \text{ (Message Type 10)} \end{cases}$$

where

if using message Type 27, δ_{UDRE} is a region-specific term as defined in section 3.5.4.9,
if using message Type 28, δ_{UDRE} is a satellite-specific term as defined in section 3.5.5.6.2.5,
if using neither message, $\delta_{UDRE} = 1$.

If fast corrections and long-term corrections/GEO ranging parameters are applied, but degradation parameters are not applied:

$$\sigma^2_{i,flt} = [(\sigma_{i,UDRE})(\delta_{UDRE}) + 8\text{m}]^2$$

3.5.5.6.2.1 Fast correction degradation. The degradation parameter for fast correction data is:

$$\varepsilon_{fc} = \frac{a(t - t_u + t_{lat})^2}{2}$$

where

t = the current time;
t_u = ($UDREI_i$ reference time): if $IODF_j \neq 3$, the start time of the SNT 1-second epoch that is coincident with the start of the transmission of the message block that contains the most recent $UDREI_i$ data (Type 2 to 6, or Type 24 messages) that matches the $IODF_j$ of the fast correction being used. If $IODF_j = 3$, the start time of the epoch of the SNT 1-second epoch that is coincident with the start of transmission of the message that contains the fast correction for the i[th] satellite; and
t_{lat} = (as defined in 3.5.4.7).

Note.— For UDREs broadcast in Type 2 to 5, and Type 24 messages, t_u equals the time of applicability of the fast corrections since they are in the same message. For UDREs broadcast in Type 6 message and if the IODF = 3, t_u also equals the time of applicability of the fast corrections (t_{0f}). For UDREs broadcast in Type 6 message and IODF ≠ 3, t_u is defined to be the time of transmission of the first bit of Type 6 message at the GEO.

3.5.5.6.2.2 Range rate correction degradation

3.5.5.6.2.2.1 If the RRC = 0, then $\varepsilon_{rrc} = 0$.

3.5.5.6.2.2.2 If the RRC ≠ 0 and IODF ≠ 3, the degradation parameter for fast correction data is:

$$\varepsilon_{rrc} = \begin{cases} 0, & \text{if } (IODF_{current} - IODF_{previous}) MOD3 = 1 \\ \left(\frac{a I_{fc}}{4} + \frac{B_{rrc}}{\Delta t}\right)(t - t_{of}), & \text{if } (IODF_{current} - IODF_{previous}) MOD3 \neq 1 \end{cases}$$

3.5.5.6.2.2.3 If RRC ≠ 0 and IODF = 3, the degradation parameter for range rate data is:

$$\varepsilon_{rrc} = \begin{cases} 0, & \text{if } \left|\Delta t - \frac{I_{fc}}{2}\right| = 0 \\ \left(\frac{a\left|\Delta t - \frac{I_{fc}}{2}\right|}{2} + \frac{B_{rrc}}{\Delta t}\right)(t - t_{0f}), & \text{if } \left|\Delta t - \frac{I_{fc}}{2}\right| \neq 0 \end{cases}$$

where

t = the current time;
$IODF_{current}$ = IODF associated with most recent fast correction;
$IODF_{previous}$ = IODF associated with previous fast correction;
Δt = $t_{i,0f} - t_{i,0f\_previous}$; and
I_{fc} = the user time-out interval for fast corrections.

3.5.5.6.2.3 Long-term correction degradation

3.5.5.6.2.3.1 Core satellite constellation(s)

3.5.5.6.2.3.1.1 For velocity code = 1, the degradation parameter for long-term corrections of satellite i is:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{i,LT} < t < t_{i,LT} + I_{ltc\_v1} \\ C_{ltc\_lsb} + C_{ltc\_v1} \max\left(0, t_{i,LT} - t, t - t_{i,LT} - I_{ltc\_v1}\right), & \text{otherwise} \end{cases}$$

3.5.5.6.2.3.1.2 For velocity code = 0, the degradation parameter for long-term corrections is:

$$\varepsilon_{ltc} = C_{ltc\_v0} \left\lfloor \frac{t - t_{ltc}}{I_{ltc\_v0}} \right\rfloor$$

where

t = the current time;
t_{ltc} = the time of transmission of the first bit of the long-term correction message at the GEO; and
$\lfloor x \rfloor$ = the greatest integer less than x.

3.5.5.6.2.3.2 GEO satellites. The degradation parameter for long-term corrections is:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{0,GEO} < t < t_{0,GEO} + I_{GEO} \\ C_{geo\_lsb} + C_{geo\_v} \max\left(0,\ t_{0,GEO} - t,\ t - t_{0,GEO} - I_{geo}\right), & \text{otherwise} \end{cases}$$

where t = the current time.

Note.— When long-term corrections are applied to a GEO satellite, the long-term correction degradation is applied and the GEO navigation message degradation is not applied.

3.5.5.6.2.4 Degradation for en-route through non-precision approach

$$\varepsilon_{er} = \begin{cases} 0, & \text{if neither fast nor long-term corrections have timed out for precision approach/approach with vertical guidance} \\ C_{er}, & \text{if fast or long-term corrections have timed out for precision approach/approach with vertical guidance} \end{cases}$$

3.5.5.6.2.5 UDRE degradation factor calculated with message Type 28 data. The δUDRE is:

$$\delta_{UDRE} = \sqrt{I^T \cdot C \cdot I} + \varepsilon_c$$

where

$$I = \begin{bmatrix} i_x \\ i_y \\ i_z \\ 1 \end{bmatrix},$$

$\begin{bmatrix} i_x \\ i_y \\ i_z \end{bmatrix}$ = the unit vector from the user to the satellite in the WGS-84 ECEF coordinate frame

$$C = R^T \cdot R$$

$$\varepsilon_C = C_{covariance} \cdot SF$$

$$SF = 2^{scale\ exponent-5}$$

$$R = E \cdot SF$$

$$E = \begin{bmatrix} E_{1,1} & E_{1,2} & E_{1,3} & E_{1,4} \\ 0 & E_{2,2} & E_{2,3} & E_{2,4} \\ 0 & 0 & E_{3,3} & E_{3,4} \\ 0 & 0 & 0 & E_{4,4} \end{bmatrix}$$

3.5.5.6.3 Definition of ionospheric correction error model

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

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

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 (W_n) and grid points selected for the ionospheric correction (3.5.5.5).

If degradation parameters are used, for each grid point:

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

where

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

t = the current time;

t_{iono} = the time of transmission of the first bit of the ionospheric correction message at the GEO; and

$\lfloor x \rfloor$ = the greatest integer less than x.

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

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

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 $(f_{GLONASS}/f_{GPS})^2$.

3.5.5.6.3.2 Ionospheric corrections. If SBAS-based ionospheric corrections are not applied, σ^2_{UIRE} is:

$$\sigma^2_{UIRE} = MAX\left\{\left(\frac{T_{iono}}{5}\right)^2, \left(F_{pp} \cdot \tau_{vert}\right)^2\right\}$$

where

T_{iono} = the ionospheric delay estimated by the chosen model (GPS correction or other model); F_{pp} = (as defined in 3.5.5.5.2);

where

T_{iono} = the ionospheric delay estimated by the chosen model (GPS correction or other model);

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

$$\tau_{vert} = \begin{cases} 9\ m, & 0 \le |\phi_{pp}| \le 20 \\ 4.5\ m, & 20 < |\phi_{pp}| \le 55; \text{and} \\ 6\ m, & 55 < |\phi_{pp}| \end{cases}$$

ϕ_{pp} = latitude of the ionospheric pierce point.

3.5.6 Message Tables

Each SBAS message shall be coded in accordance with the corresponding message format defined in Tables B-37 through B-53. All signed parameters in these tables shall be represented in two's complement, with the sign bit occupying the MSB.

Note.— The range for the signed parameters is smaller than indicated, as the maximum positive value is constrained to be one value less (the indicated value minus the resolution).

Table A-37. Type 0 "Do Not Use" message

Data content	Bits used	Range of values	Resolution
Spare	212	—	—

Table A-38. Type 1 PRN mask message

Data content	Bits used	Range of values	Resolution
For each of 210 PRN code numbers			
Mask value	1	0 or 1	1
IODP	2	0 to 3	1

Note.— All parameters are defined in 3.5.4.1.

Table A-39. Types 2 to 5 fast correction message

Data content	Bits used	Range of values	Resolution
$IODF_j$	2	0 to 3	1
IODP	2	0 to 3	1
For 13 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 13 slots			
$UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—

1. The parameters $IODF_j$ and FC_i are defined in 3.5.4.4.2.

2. The parameter IODP is defined in 3.5.4.1.

3. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table A-40. Type 6 integrity message

Data content	Bits used	Range of values	Resolution
$IODF_2$	2	0 to 3	1
$IODF_3$	2	0 to 3	1
$IODF_4$	2	0 to 3	1
$IODF_5$	2	0 to 3	1
For 51 satellites (ordered by PRN mask number)			
$UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—
1. The parameters $IODF_j$ are defined in 3.5.4.4.2.
2. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table A-41. Type 7 fast correction degradation factor message

Data content	Bits used	Range of values	Resolution
System latency (t_{lat})	4	0 to 15 s	1 s
IODP	2	0 to 3	1
Spare	2	—	—
For 51 satellites (ordered by PRN mask number)			
Degradation factor indicator (ai_i)	4	(see Table B-34)	(see Table B-34)

Notes.—
1. The parameters t_{lat} and ai_i are defined in 3.5.4.7.
2. The parameter IODP is defined in 3.5.4.1.

Table A-42. Type 9 ranging function message

Data content	Bits used	Range of values	Resolution
Reserved	8	—	—
$t_{0,GEO}$	13	0 to 86 384 s	16 s
URA	4	(see Table B-26)	(see Table B-26)
X_G	30	±42 949 673 m	0.08 m
Y_G	30	±42 949 673 m	0.08 m
Z_G	25	±6 710 886.4 m	0.4 m
$\dot{X}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Y}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Z}_G$	18	±524.288 m/s	0.004 m/s
$\ddot{X}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Y}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Z}_G$	10	±0.032 m/s^2	0.0000625 m/s^2
a_{Gf0}	12	$\pm 0.9537 \times 10^{-6}$ s	2^{-31} s
a_{Gf1}	8	$\pm 1.1642 \times 10^{-10}$ s/s	2^{-40} s/s

Note.— All parameters are defined in 3.5.4.2.

Table A-43. Type 10 degradation parameter message

Data content	Bits used	Range of values	Resolution
B_{rrc}	10	0 to 2.046 m	0.002 m
C_{ltc_lsb}	10	0 to 2.046 m	0.002 m
C_{ltc_v1}	10	0 to 0.05115 m/s	0.00005 m/s
I_{ltc_v1}	9	0 to 511 s	1 s
C_{ltc_v0}	10	0 to 2.046 m	0.002 m
I_{ltc_v0}	9	0 to 511 s	1 s
C_{geo_lsb}	10	0 to 0.5115 m	0.0005 m
C_{geo_v}	10	0 to 0.05115 m/s	0.00005 m/s
I_{geo}	9	0 to 511 s	1 s
C_{er}	6	0 to 31.5 m	0.5 m
C_{iono_step}	10	0 to 1.023 m	0.001 m
I_{iono}	9	0 to 511 s	1 s
$C_{iono\ ramp}$	10	0 to 0.005115 m/s	0.000005 m/s
RSS_{UDRE}	1	0 or 1	1
RSS_{iono}	1	0 or 1	1
$C_{covariance}$	7	0 to 12.7	0.1
Spare	81	—	—

Note.— All parameters are defined in 3.5.4.7.

Table A-44. Type 12 SBAS network time/UTC message

Data content	Bits used	Range of values	Resolution
A_{1SNT}	24	$\pm 7.45 \times 10^{-9}$ s/s	2^{-50} s/s
A_{0SNT}	32	±1 s	2^{-30} s
t_{0t}	8	0 to 602 112 s	4 096 s
WN_t	8	0 to 255 weeks	1 week
Δt_{LS}	8	±128 s	1 s
WN_{LSF}	8	0 to 255 weeks	1 week
DN	8	1 to 7 days	1 day
Δt_{LSF}	8	±128 s	1 s
UTC standard identifier	3	(see Table B-35)	(see Table B-35)
GPS time-of-week (TOW)	20	0 to 604 799 s	1 s
GPS week number (WN)	10	0 to 1 023 weeks	1 week
GLONASS indicator	1	0 or 1	1
$\delta a_{i,GLONASS}$ (*Note 2*)	24	$\pm 2.0 \cdot 10^{-8}$ s	$2.0 \cdot 10^{-31}$ s
Spare	50	—	—

Notes.—
1. *All parameters are defined in 3.5.4.8.*
2. *Applies only if SBAS sends GLONASS timing information in message Type 12 (see 3.5.7.4.4, Timing data).*

Table A-45. Type 17 GEO almanac message

Data content	Bits used	Range of values	Resolution
For each of 3 satellites			
Reserved	2	0	—
PRN code number	8	0 to 210	1
Health and status	8	—	—
$X_{G,A}$	15	±42 598 400 m	2 600 m
$Y_{G,A}$	15	±42 598 400 m	2 600 m
$Z_{G,A}$	9	±6 656 000 m	26 000 m
$\dot{X}_{G,A}$	3	±40 m/s	10 m/s
$\dot{Y}_{G,A}$	3	±40 m/s	10 m/s
$\dot{Z}_{G,A}$	4	±480 m/s	60 m/s
$t_{almanac}$ (applies to all three satellites)	11	0 to 86 336 s	64 s

Note.— All parameters are defined in 3.5.4.3.

Table A-46. Type 18 IGP mask message

Data content	Bits used	Range of values	Resolution
Number of IGP bands	4	0 to 11	1
IGP band identifier	4	0 to 10	1
Issue of data — ionosphere ($IODI_k$)	2	0 to 3	1
For 201 IGPs			
IGP mask value	1	0 or 1	1
Spare	1	—	—

Note.— All parameters are defined in 3.5.4.6.

Table A-47. Type 24 mixed fast/long-term satellite error correction message

Data content	Bits used	Range of values	Resolution
For 6 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 6 slots			
$UDREI_i$	4	(see Table B-31)	(see Table B-31)
IODP	2	0 to 3	1
Fast correction type identifier	2	0 to 3	1
$IODF_j$	2	0 to 3	1
Spare	4	—	—
Type 25 half-message	106	—	—

Notes.—
1. *The parameters fast correction type identifier, $IODF_j$, and FC_i are defined in 3.5.4.4.1.*
2. *The parameter IODP is defined in 3.5.4.1.*
3. *The parameter $UDREI_i$ is defined in 3.5.4.5.*
4. *The long-term satellite error correction message is divided into two half-messages. The half message for a velocity code = 0 is defined in Table B-48. The half message for a velocity code = 1 is defined in Table B-49.*

Table A-48. Type 25 long-term satellite error correction half message

(VELOCITY CODE = 0)

Data content	Bits used	Range of values	Resolution
Velocity Code = 0	1	0	1
For 2 Satellites			
PRN mask number	6	0 to 51	1
Issue of data (IOD_i)	8	0 to 255	1
δx_i	9	±32 m	0.125 m
δy_i	9	±32 m	0.125 m
δz_i	9	±32 m	0.125 m
$\delta a_{i,f0}$	10	$\pm 2^{-22}$ s	2^{-31} s
IODP	2	0 to 3	1
Spare	1	—	—

Notes.—
1. The parameters PRN mask number and IODP are defined in 3.5.4.1.
2. All other parameters are defined in 3.5.4.4.1.

Table A-49. Type 25 long-term satellite error correction half message

(VELOCITY CODE = 1)

Data content	Bits used	Range of values	Resolution
For 1 Satellite			
Velocity Code = 1	1	1	1
PRN mask number	6	0 to 51	1
Issue of data (IOD_i)	8	0 to 255	1
δx_i	11	±128 m	0.125 m
δy_i	11	±128 m	0.125 m
δz_i	11	±128 m	0.125 m
$\delta a_{i,f0}$	11	$\pm 2^{-21}$ s	2^{-31} s
$\delta \dot{x}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta \dot{y}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta \dot{z}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta a_{i,f1}$	8	$\pm 2^{-32}$ s/s	2^{-39} s/s
Time-of-applicability ($t_{i,LT}$)	13	0 to 86 384 s	16 s
IODP	2	0 to 3	1

Notes.—
1. The parameters PRN mask number and IODP are defined in 3.5.4.1.
2. All other parameters are defined in 3.5.4.4.1.