COVER SHEET TO AMENDMENT 84

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERONAUTICAL TELECOMMUNICATIONS

ANNEX 10
TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
RADIO NAVIGATION AIDS

SIXTH EDITION — JULY 2006

INTERNATIONAL CIVIL AVIATION ORGANIZATION

Checklist of Amendments to Annex 10, Volume I

	Effective date	*Date of applicability*
Sixth Edition (incorporates Amendments 1 to 81)	17 July 2006	23 November 2006
Amendment 82 (adopted by the Council on 26 February 2007)	16 July 2007	22 November 2007
Amendment 83 (adopted by the Council on 10 March 2008)	20 July 2008	20 November 2008
Amendment 84 (adopted by the Council on 6 March 2009) Replacement pages (iii), (iv), (v), (xviii), 1-2, 2-1, 2-2, 2-3, 3-9 to 3-17, 3-19 to 3-32, 3-36, 3-39 to 3-52, 3-54, 3-55, 3-56, 3-76, 3-85 to 3-99, APP B-84, ATT C-1 to ATT C-74, ATT G-7 to ATT G-12, ATT G-19 to ATT G-22, ATT G-24 to ATT G-28, ATT G-57, ATT G-85, ATT G-85A, ATT G-85B	20 July 2009	19 November 2009

Transmittal note

Amendment 84

to the

International Standards and
Recommended Practices

AERONAUTICAL TELECOMMUNICATIONS

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

1. Insert the following replacement pages in Annex 10, Volume I (Sixth Edition) to incorporate Amendment 84 which becomes applicable on 19 November 2009:

a)	Pages (iii), (iv) and (v)	— Table of Contents
b)	Pages (xvii) and (xviii)	— Foreword
c)	Pages 1-1 and 1-2	— Chapter 1
d)	Replace all of Chapter 2 with new pages 2-1, 2-2 and 2-3	— Chapter 2
e)	Pages 3-9 to 3-56; 3-75 and 3-76; 3-85 to 3-100	— Chapter 3
f)	Pages APP B-83 and APP B-84	— Appendix B to Chapter 3
g)	Replace all of Attachment C with new pages ATT C-1 to ATT C-74	— Attachment C
h)	Pages ATT G-7 to ATT G-12; ATT G-19 to ATT G-28; ATT G-57 and ATT G-58; ATT G-85, ATT G-85A, ATT G-85B, and ATT G-86	— Attachment G

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

20/7/09

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ATTACHMENTS

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Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
70	ANC; Third Meeting of the Aeronautical Fixed Service Systems Planning for Data Interchange Panel; 34th Meeting of the European Air Navigation Planning Group	Restructuring of Annex 10 into five volumes; deletion of obsolete specifications and guidance material on manual Morse code procedures and teletypewriter systems; inclusion of material on common ICAO data interchange network (CIDIN).	20 March 1995 24 July 1995 9 November 1995
71	ANC; Special COM/OPS Divisional Meeting (1995); 12th, 13th and 14th Meetings of the All Weather Operations Panel; Secretariat proposals for deletion of obsolete material	Finalization of SARPs and guidance material for the microwave landing system (MLS), incorporation of a new strategy for introduction and application of non-visual aids to approach and landing in place of the ILS/MLS transition plan; relocation of material to Volumes III, IV and V, as appropriate; deletion of obsolete specifications for Consol and Loran-A systems and guidance material on the utilization of facilities, research, development and evaluation.	12 March 1996 15 July 1996 7 November 1996
72	—	No change.	—
73	Air Navigation Commission	Introduction of Human Factors-related material.	19 March 1998 20 July 1998 5 November 1998
74	Sixteenth Meeting of the All Weather Operations Panel; Air Navigation Commission	Introduction of: a) required navigation performance (RNP) for approach, landing and departure operation; b) updating of specifications for instrument landing system (ILS) and microwave landing system (MLS); and c) associated guidance material.	18 March 1999 19 July 1999 4 November 1999
75	—	No change.	—
76	Third meeting of the Global Navigation Satellite System Panel (GNSSP); proposal by the United Kingdom for continuity of service requirements for ILS and MLS	Global navigation satellite system (GNSS); continuity of service requirements for ILS localizers and MLS azimuth facilities used in support of Category IIIA operations; updating of references to the ITU Radio Regulations.	12 March 2001 16 July 2001 1 November 2001
77	Global Navigation Satellite System Panel (GNSSP)	Incorporation of GLONASS-related technical specifications in the satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS) sections of GNSS requirements; provision for use of GBAS positioning service in support of terminal area navigation (RNAV) operations; provision for use of new Message Type 28 to enhance performance of SBAS; and incorporation of additional guidance material and clarifications/editorial corrections to SARPs and guidance material.	27 February 2002 15 July 2002 28 November 2002
78	—	No change.	—

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
79	Fourth meeting of the Global Navigation Satellite System Panel	Changes to GNSS SARPs and related guidance material concerning performance specifications for approach with vertical guidance (APV); global positioning system (GPS) selective availability (SA) discontinuation and clarification of signal power level; specifications for modernized GLObal NAvigation Satellite System (GLONASS-M); frequency planning criteria for ground-based augmentation system (GBAS) and a number of other enhancements.	23 February 2004 12 July 2004 25 November 2004
80	Eleventh Air Navigation Conference	Updates to the strategy for introduction and application of non-visual aids to approach and landing.	25 February 2005 11 July 2005 24 November 2005
81	Navigation Systems Panel (NSP)	a) Introduction of ground-based regional augmentation system (GRAS) Standards and Recommended Practices (SARPs); b) Amendments to SARPs for instrument landing system (ILS), distance measuring equipment (DME) and microwave landing system (MLS).	24 February 2006 17 July 2006 23 November 2006
82	Aeronautical Communications Panel (ACP)	Identification of the universal access transceiver (UAT) operating frequency.	26 February 2007 16 July 2007 22 November 2007
83	Secretariat with the assistance of the Required Navigation Performance and Special Operations Requirements Study Group (RNPSORSG); Navigation Systems Panel (NSP)	a) Amendments to definitions and Standards to align required navigation performance (RNP) and area navigation (RNAV) terminology with the performance-based navigation (PBN) concept; and b) Amendments to resolve certain navigation systems implementation issues and to reflect the evolution of existing global navigation satellite systems (GNSS) and equipment.	10 March 2008 20 July 2008 20 November 2008
84	Navigation Systems Panel (NSP)	a) update and reorganize the material on general provisions for radio navigation aids; b) amend obsolete or ambiguous provisions for the instrument landing system (ILS); c) amend obsolete or ambiguous provisions material for the very high frequency (VHF) omnidirectional radio range (VOR); d) delete material on testing of non-directional beacons (NDB), which duplicates existing guidance contained in Doc 8071, *Manual on Testing of Radio Navigation Aids*; e) reflect the results of the review of the distance monitoring equipment (DME) issues identified in Recommendations 6/14 and 6/15 of the Eleventh Air Navigation Conference; f) update the accuracy Standard in light of actual avionics performance, and clarify and simplify existing material; and g) address potential safety issues identified in the course of microwave landing system (MLS) Category III certification.	6 March 2009 20 July 2009 19 November 2009

* Did not affect any Standards or Recommended Practices.

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

CHAPTER 1. DEFINITIONS

Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies *(Doc 9718).*

Note 2.— Annex 10, Volume I includes Standards and Recommended Practices for certain forms of equipment for air navigation aids. While the Contracting State will determine the necessity for specific installations in accordance with the conditions prescribed in the relevant Standard or Recommended Practice, review of the need for specific installation and the formulation of ICAO opinion and recommendations to Contracting States concerned is carried out periodically by Council, ordinarily on the basis of recommendations of Regional Air Navigation Meetings (Doc 8144 — Directives to Regional Air Navigation Meetings and Rules of Procedure for their Conduct).

When the following terms are used in this volume, they have the following meanings:

Altitude. The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).

Area navigation (RNAV). 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.

Note.— Area navigation includes performance-based navigation as well as other operations that do not meet the definition of performance-based navigation.

Effective acceptance bandwidth. The range of frequencies with respect to the assigned frequency for which reception is assured when all receiver tolerances have been taken into account.

Effective adjacent channel rejection. The rejection that is obtained at the appropriate adjacent channel frequency when all relevant receiver tolerances have been taken into account.

Elevation. 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. A radio navigation service whose disruption has a significant impact on operations in the affected airspace or aerodrome.

Fan marker beacon. A type of radio beacon, the emissions of which radiate in a vertical fan-shaped pattern.

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Human Factors principles. 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.

Mean power (of a radio transmitter). The average power supplied to the antenna transmission line by a transmitter during an interval of time sufficiently long compared with the lowest frequency encountered in the modulation taken under normal operating conditions.

Note.— A time of 1/10 second during which the mean power is greatest will be selected normally.

Navigation specification. A set of aircraft and flight crew requirements needed to support performance-based navigation operations within a defined airspace. There are two kinds of navigation specifications:

Required navigation performance (RNP) specification. A navigation specification based on area navigation that includes the requirement for performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

Area navigation (RNAV) specification. A navigation specification based on area navigation that does not include the requirement for performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

Note.1— The Performance-based Navigation (PBN) Manual *(Doc 9613), Volume II, contains detailed guidance on navigation specifications.*

Note 2.— The term RNP, previously defined as "a statement of the navigation performance necessary for operation within a defined airspace", has been removed from this Annex as the concept of RNP has been overtaken by the concept of PBN. The term RNP in this Annex is now solely used in the context of navigation specifications that require performance monitoring and alerting, e.g. RNP 4 refers to the aircraft and operating requirements, including a 4 NM lateral performance with on-board performance monitoring and alerting that are detailed in Doc 9613.

Performance-based navigation (PBN). Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.

Note.— Performance requirements are expressed in navigation specifications (RNAV specification, RNP specification) in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

Pressure-altitude. An atmospheric pressure expressed in terms of altitude which corresponds to that pressure in the Standard Atmosphere.

Protected service volume. A part of the facility coverage where the facility provides a particular service in accordance with relevant SARPs and within which the facility is afforded frequency protection.

Radio navigation service. A service providing guidance information or position data for the efficient and safe operation of aircraft supported by one or more radio navigation aids.

Touchdown. The point where the nominal glide path intercepts the runway.

Note.— "Touchdown" as defined above is only a datum and is not necessarily the actual point at which the aircraft will touch the runway.

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

CHAPTER 2. GENERAL PROVISIONS FOR RADIO NAVIGATION AIDS

2.1 Standard radio navigation aids

2.1.1 The standard radio navigation aids shall be:

a) the instrument landing system (ILS) conforming to the Standards contained in Chapter 3, 3.1;

b) the microwave landing system (MLS) conforming to the Standards contained in Chapter 3, 3.11;

c) the global navigation satellite system (GNSS) conforming to the Standards contained in Chapter 3, 3.7;

d) the VHF omnidirectional radio range (VOR) conforming to the Standards contained in Chapter 3, 3.3;

e) the non-directional radio beacon (NDB) conforming to the Standards contained in Chapter 3, 3.4;

f) the distance measuring equipment (DME) conforming to the Standards contained in Chapter 3, 3.5; and

g) the en-route VHF marker beacon conforming to the Standards contained in Chapter 3, 3.6.

Note 1.— Since visual reference is essential for the final stages of approach and landing, the installation of a radio navigation aid does not obviate the need for visual aids to approach and landing in conditions of low visibility.

Note 2.— It is intended that introduction and application of radio navigation aids to support precision approach and landing operations will be in accordance with the strategy shown in Attachment B.

Note 3.— Categories of precision approach and landing operations are classified in Annex 6, Part I, Chapter 1.

Note 4.— Information on operational objectives associated with ILS facility performance categories is given in Attachment C, 2.1 and 2.14.

Note 5.— Information on operational objectives associated with MLS facility performance is given in Attachment G, 11.

2.1.2 Differences in radio navigation aids in any respect from the Standards of Chapter 3 shall be published in an Aeronautical Information Publication (AIP).

2.1.3 Wherever there is installed a radio navigation aid that is neither an ILS nor an MLS, but which may be used in whole or in part with aircraft equipment designed for use with the ILS or MLS, full details of parts that may be so used shall be published in an Aeronautical Information Publication (AIP).

Note.— This provision is to establish a requirement for promulgation of relevant information rather than to authorize such installations.

2.1.4 GNSS-specific provisions

2.1.4.1 It shall be permissible to terminate a GNSS satellite service provided by one of its elements (Chapter 3, 3.7.2) on the basis of at least a six-year advance notice by a service provider.

2.1.4.2 **Recommendation.—** *A State that approves GNSS-based operations should ensure that GNSS data relevant to those operations are recorded.*

Note 1.— These recorded data are primarily intended for use in accident and incident investigations. They may also support periodic confirmation that accuracy, integrity, continuity and availability are maintained within the limits required for the operations approved.

Note 2.— Guidance material on the recording of GNSS parameters is contained in Attachment D, 11.

2.1.4.3 **Recommendation.—** *Recordings should be retained for a period of at least 14 days. When the recordings are pertinent to accident and incident investigations, they should be retained for longer periods until it is evident that they will no longer be required.*

2.1.5 Precision approach radar

2.1.5.1 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 the Standards contained in Chapter 3, 3.2.

Note 1.— The precision approach radar (PAR) element of the precision approach radar system may be installed and operated without the surveillance radar element (SRE), when it is determined that the SRE is not necessary to meet the requirements of air traffic control for the handling of aircraft.

Note 2.— Although SRE is not considered, in any circumstances, a satisfactory alternative to the precision approach radar system, the SRE may be installed and operated without the PAR for the assistance of air traffic control in handling aircraft intending to use a radio navigation aid, or for surveillance radar approaches and departures.

2.1.6 **Recommendation.—** *When a radio navigation aid is provided to support precision approach and landing, it should 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 (manual or automatic) with, the desired reference path.*

Note.— DME, GNSS, NDB, VOR and aircraft navigation systems have been used for such purposes.

2.2 Ground and flight testing

2.2.1 Radio navigation aids of the types covered by the specifications in Chapter 3 and available for use by aircraft engaged in international air navigation shall be the subject of periodic ground and flight tests.

Note.— Guidance on the ground and flight testing of ICAO standard facilities, including the periodicity of the testing, is contained in Attachment C and in the Manual on Testing of Radio Navigation Aids *(Doc 8071).*

2.3 Provision of information on the operational status of radio navigation services

2.3.1 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(s) with which they are concerned, on a timely basis consistent with the use of the service(s) involved.

2.4 Power supply for radio navigation aids and communication systems

2.4.1 Radio navigation aids and ground elements of communication systems of the types specified in Annex 10 shall be provided with suitable power supplies and means to ensure continuity of service consistent with the use of the service(s) involved.

Note.— Guidance material on power supply switch-over is contained in Attachment C, 8.

2.5 Human Factors considerations

2.5.1 **Recommendation.—** *Human Factors principles should be observed in the design and certification of radio navigation aids.*

Note.— Guidance material on Human Factors principles can be found in the Human Factors Training Manual *(Doc 9683) and Circular 249* (Human Factors Digest No. 11 — Human Factors in CNS/ATM Systems).

Note 2.— For two-frequency systems, the standard for maximum sum of modulation depths does not apply at or near azimuths where the course and clearance carrier signal levels are equal in amplitude (i.e. at azimuths where both transmitting systems have a significant contribution to the total modulation depth).

Note 3.— The standard for minimum sum of modulation depths is based on the malfunctioning alarm level being set as high as 30 per cent as stated in 2.3.3 of Attachment C.

3.1.3.5.3.7 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 65 per cent within 10 degrees of the course line and shall not exceed 78 per cent at any other point around the localizer.

3.1.3.5.4 **Recommendation.—** *Undesired frequency and phase modulation on ILS localizer radio frequency carriers that can affect the displayed DDM values in localizer receivers should be minimized to the extent practical.*

Note.— Relevant guidance material is given in 2.15 of Attachment C.

3.1.3.6 *Course alignment accuracy*

3.1.3.6.1 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);

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

3.1.3.6.2 **Recommendation.—** *For Facility Performance Category II localizers, the mean course line should be adjusted and maintained within limits equivalent to plus or minus 4.5 m (15 ft) displacement from runway centre line at the ILS reference datum.*

Note 1.— It is intended that Facility Performance Categories II and III installations be adjusted and maintained so that the limits specified in 3.1.3.6.1 and 3.1.3.6.2 are reached on very rare occasions. It is further intended that design and operation of the total ILS ground system be of sufficient integrity to accomplish this aim.

Note 2.— It is intended that new Category II installations are to meet the requirements of 3.1.3.6.2.

Note 3.— Guidance material on measurement of localizer course alignment is given in 2.1.3 of Attachment C.

3.1.3.7 *Displacement sensitivity*

3.1.3.7.1 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. For Facility Performance Category I localizers on runway codes 1 and 2, the nominal displacement sensitivity shall be achieved at the ILS Point "B". The maximum course sector angle shall not exceed six degrees.

Note.— Runway codes 1 and 2 are defined in Annex 14.

3.1.3.7.2 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.

3.1.3.7.3 **Recommendation.—** *For Facility Performance Category II — ILS, displacement sensitivity should be adjusted and maintained within the limits of plus or minus 10 per cent where practicable.*

Note 1.— The figures given in 3.1.3.7.1, 3.1.3.7.2 and 3.1.3.7.3 are based upon a nominal sector width of 210 m (700 ft) at the appropriate point, i.e. ILS Point "B" on runway codes 1 and 2, and the ILS reference datum on other runways.

Note 2.— Guidance material on the alignment and displacement sensitivity of localizers using two radio frequency carriers is given in 2.7 of Attachment C.

Note 3.— Guidance material on measurement of localizer displacement sensitivity is given in 2.9 of Attachment C.

3.1.3.7.4 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. From that angle to plus or minus 10 degrees, the DDM shall not be less than 0.180. From plus or minus 10 degrees to plus or minus 35 degrees, the DDM shall not be less than 0.155. 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.

Note 1.— The linearity of change of DDM with respect to angular displacement is particularly important in the neighbourhood of the course line.

Note 2.— The above DDM in the 10-35 degree sector is to be considered a minimum requirement for the use of ILS as a landing aid. Wherever practicable, a higher DDM, e.g. 0.180, is advantageous to assist high speed aircraft to execute large angle intercepts at operationally desirable distances provided that limits on modulation percentage given in 3.1.3.5.3.6 are met.

Note 3.— Wherever practicable, the localizer capture level of automatic flight control systems is to be set at or below 0.175 DDM in order to prevent false localizer captures.

3.1.3.8 *Voice*

3.1.3.8.1 Facility Performance Categories I and II localizers may provide a ground-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.

3.1.3.8.2 Category III localizers shall not provide such a 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.

3.1.3.8.3 If the channel is provided, it shall conform with the following Standards:

3.1.3.8.3.1 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. 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.

3.1.3.8.3.2 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:

a) the ratio of peak modulation depth due to the radiotelephone communications to that due to the identification signal is approximately 9:1;

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

3.1.3.8.3.3 The audio frequency characteristics of the radiotelephone 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.

3.1.3.9 *Identification*

3.1.3.9.1 The localizer shall provide for the simultaneous transmission of an identification signal, specific to the runway and approach direction, on the same radio frequency carrier or carriers as used for the localizer function. The transmission of the identification signal shall not interfere in any way with the basic localizer function.

3.1.3.9.2 The identification signal shall be produced by Class A2A modulation of the radio frequency carrier or carriers using a modulation tone of 1 020 Hz within plus or minus 50 Hz. 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 (see 3.1.3.8.3.2). The emissions carrying the identification signal shall be horizontally polarized. 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.

3.1.3.9.3 The identification signal shall employ the International Morse Code and consist of two or three letters. It may 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.

3.1.3.9.4 The identification signal shall be transmitted by dots and dashes at a speed corresponding to approximately seven words per minute, and 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. When the transmissions of the localizer are not available for operational use, as, for example, after removal of navigation components, or during maintenance or test transmissions, the identification signal shall be suppressed. The dots shall have a duration of 0.1 second to 0.160 second. The dash duration shall be typically three times the duration of a dot. The interval between dots and/or dashes shall be equal to that of one dot plus or minus 10 per cent. The interval between letters shall not be less than the duration of three dots.

3.1.3.10 *Siting*

3.1.3.10.1 For Facility Performance Categories II and III, the localizer antenna system shall be located on the extension on the centre line of the runway at the stop end, and the equipment shall be adjusted so that the course lines will be in a vertical plane containing the centre line of the runway served. The antenna height and location shall be consistent with safe obstruction clearance practices.

3.1.3.10.2 For Facility Performance Category I, the localizer antenna system shall be located and adjusted as in 3.1.3.10.1, unless site constraints dictate that the antenna be offset from the centre line of the runway.

3.1.3.10.2.1 The offset localizer system shall be located and adjusted in accordance with the offset ILS provisions of the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II, and the localizer standards shall be referenced to the associated fictitious threshold point.

3.1.3.11 *Monitoring*

3.1.3.11.1 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 3.1.3.11.3.1, if any of the conditions stated in 3.1.3.11.2 persist:

a) radiation to cease; and

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

3.1.3.11.2 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 3.1.3.3, 3.1.3.4 or 3.1.3.5 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 3.1.3.3, 3.1.3.4 and 3.1.3.5;

Note.— It is important to recognize that a frequency change resulting in a loss of the frequency difference specified in 3.1.3.2.1 may produce a hazardous condition. This problem is of greater operational significance for Categories II and III installations. As necessary, this problem can be dealt with through special monitoring provisions or highly reliable circuitry.

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

Note.— In selecting the power reduction figure to be employed in monitoring referred to in 3.1.3.11.2 e), particular attention is directed to vertical and horizontal lobe structure (vertical lobing due to different antenna heights) of the combined radiation systems when two carriers are employed. Large changes in the power ratio between carriers may result in low clearance areas and false courses in the off-course areas to the limits of the vertical coverage requirements specified in 3.1.3.3.1.

3.1.3.11.2.1 **Recommendation.—** *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 should include the case when 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.*

3.1.3.11.3 The total period of radiation, including period(s) of zero radiation, outside the performance limits specified in a), b), c), d), e) and f) of 3.1.3.11.2 shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the localizer.

3.1.3.11.3.1 The total period referred to under 3.1.3.11.3 shall not exceed under any circumstances:

10 seconds for Category I localizers;

5 seconds for Category II localizers;

2 seconds for Category III localizers.

Note 1.— The total time periods specified are never-to-be-exceeded limits and are intended to protect aircraft in the final stages of approach against prolonged or repeated periods of localizer guidance outside the monitor limits. For this reason, they include not only the initial period of outside tolerance operation but also the total of any or all periods of outside tolerance radiation including period(s) of zero radiation and time required to remove the navigation and identification components from the carrier, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent changeover(s) to localizer equipment or elements thereof.

Note 2.— From an operational point of view, the intention is that no guidance outside the monitor limits be radiated after the time periods given, and that no further attempts be made to restore service until a period in the order of 20 seconds has elapsed.

3.1.3.11.3.2 **Recommendation.—** *Where practicable, the total period under 3.1.3.11.3.1 should be reduced so as not to exceed two seconds for Category II localizers and one second for Category III localizers.*

3.1.3.11.4 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.

Note.— Guidance material on the design and operation of monitor systems is given in Attachment C, 2.1.7.

3.1.3.12 *Integrity and continuity of service requirements*

3.1.3.12.1 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.

3.1.3.12.2 **Recommendation.—** *The probability of not radiating false guidance signals should not be less than $1 - 1.0 \times 10^{-7}$ in any one landing for Facility Performance Category I localizers.*

3.1.3.12.3 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) $1 - 2 \times 10^{-6}$ 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).

3.1.3.12.4 **Recommendation.—** *The probability of not losing the radiated guidance signal should 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).*

Note.— Guidance material on integrity and continuity of service is given in Attachment C, 2.8.

3.1.4 Interference immunity performance for ILS localizer receiving systems

3.1.4.1 The ILS localizer 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,

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 ILS localizer frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the ILS localizer receiver input. Neither level shall exceed the desensitization criteria set forth in 3.1.4.2.

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

3.1.4.2 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:

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

Note 1.— The relationship is linear between adjacent points designated by the above frequencies.

Note 2.— Guidance material on immunity criteria to be used for the performance quoted in 3.1.4.1 and 3.1.4.2 is contained in Attachment C, 2.2.2.

3.1.5 UHF glide path equipment and associated monitor

Note.— θ *is used in this paragraph to denote the nominal glide path angle.*

3.1.5.1 *General*

3.1.5.1.1 The radiation from the UHF glide path antenna system shall produce a composite field pattern which is amplitude modulated by a 90 Hz and a 150 Hz tone. The pattern shall be arranged to provide a straight line descent path in the vertical plane containing the centre line of the runway, with the 150 Hz tone predominating below the path and the 90 Hz tone predominating above the path to at least an angle equal to 1.75 θ.

3.1.5.1.2 **Recommendation.—** *The ILS glide path angle should be 3 degrees. ILS glide path angles in excess of 3 degrees should not be used except where alternative means of satisfying obstruction clearance requirements are impracticable.*

3.1.5.1.2.1 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.

Note 1.— Guidance material on adjustment and maintenance of glide path angles is given in 2.4 of Attachment C.

Note 2.— Guidance material on ILS glide path curvature, alignment and siting, relevant to the selection of the height of the ILS reference datum is given in 2.4 of Attachment C and Figure C-5.

3.1.5.1.3 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.

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

3.1.5.1.5 **Recommendation.—** *The height of the ILS reference datum for Facility Performance Category I — ILS should be 15 m (50 ft). A tolerance of plus 3 m (10 ft) is permitted.*

Note 1.— In arriving at the above height values for the ILS reference datum, a maximum vertical distance of 5.8 m (19 ft) between the path of the aircraft glide path antenna and the path of the lowest part of the wheels at the threshold was assumed. For aircraft exceeding this criterion, appropriate steps may have to be taken either to maintain adequate clearance at threshold or to adjust the permitted operating minima.

Note 2.— Appropriate guidance material is given in 2.4 of Attachment C.

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

3.1.5.2 *Radio frequency*

3.1.5.2.1 The glide path equipment shall operate in the band 328.6 MHz to 335.4 MHz. Where a single radio frequency carrier is used, the frequency tolerance shall not exceed 0.005 per cent. Where two carrier glide path systems are used, the frequency tolerance shall not exceed 0.002 per cent and the nominal band occupied by the carriers shall be symmetrical about the assigned frequency. With all tolerances applied, the frequency separation between the carriers shall not be less than 4 kHz nor more than 32 kHz.

3.1.5.2.2 The emission from the glide path equipment shall be horizontally polarized.

3.1.5.2.3 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.

3.1.5.3 *Coverage*

3.1.5.3.1 The glide path equipment shall provide signals sufficient to allow satisfactory 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.

3.1.5.3.2 In order to provide the coverage for glide path performance specified in 3.1.5.3.1, the minimum field strength within this coverage sector shall be 400 microvolts per metre (minus 95 dBW/m^2). 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. For Facility Performance Categories II and III glide paths, this field strength shall be provided down to a height of 15 m (50 ft) above the horizontal plane containing the threshold.

Note 1.— The requirements in the foregoing paragraphs are based on the assumption that the aircraft is heading directly toward the facility.

Note 2.— Guidance material on significant airborne receiver parameters is given in 2.2 of Attachment C.

Note 3.— Material concerning reduction in coverage outside 8 degrees on each side of the centre line of the ILS glide path appears in 2.4 of Attachment C.

3.1.5.4 *ILS glide path structure*

3.1.5.4.1 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

3.1.5.4.2 For Facility Performance Categories II and III — 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 “A”	0.035
ILS Point “A” to ILS Point “B”	0.035 at ILS Point “A” decreasing at a linear rate to 0.023 at ILS Point “B”
ILS Point “B” to the ILS reference datum	0.023

Note 1.— The amplitudes referred to in 3.1.5.4.1 and 3.1.5.4.2 are the DDMs due to bends as realized on the mean ILS glide path correctly adjusted.

Note 2.— In regions of the approach where ILS glide path curvature is significant, bend amplitudes are calculated from the mean curved path, and not the downward extended straight line.

Note 3.— Guidance material relevant to the ILS glide path course structure is given in 2.1.4 of Attachment C.

3.1.5.5 *Carrier modulation*

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

3.1.5.5.2 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: additionally, for Facility Performance Category III equipment, the second harmonic of the 90 Hz tone shall not exceed 5 per cent;

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

3.1.5.5.2.1 **Recommendation.—** *For Facility Performance Category I — ILS, the modulating tones should be 90 Hz and 150 Hz within plus or minus 1.5 per cent where practicable.*

3.1.5.5.2.2 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 1 per cent.

3.1.5.5.3 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 within:

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

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.

Note 1.— The definition of phase relationship in this manner is not intended to imply a requirement for measurement of phase within the ILS half glide path sector.

Note 2.— Guidance material relating to such measures is given at Figure C-6 of Attachment C.

3.1.5.5.3.1 With two-frequency glide path systems, 3.1.5.5.3 shall apply to each carrier. 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 within:

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. 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, within:

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

2) for Category III — ILS glide paths: 10 degrees,

of phase relative to 150 Hz.

3.1.5.5.3.2 Alternative two-frequency glide path systems that employ audio phasing different from the normal in-phase condition described in 3.1.5.5.3.1 shall be permitted. In these alternative systems, 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 3.1.5.5.3.1.

Note.— This is to ensure correct airborne receiver operation within the glide path sector where the two carrier signal strengths are approximately equal.

3.1.5.5.4 **Recommendation.—** *Undesired frequency and phase modulation on ILS glide path radio frequency carriers that can affect the displayed DDM values in glide path receivers should be minimized to the extent practical.*

Note.— Relevant guidance material is given in 2.15 of Attachment C.

3.1.5.6 *Displacement sensitivity*

3.1.5.6.1 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.

Note.— The above is not intended to preclude glide path systems which inherently have asymmetrical upper and lower sectors.

3.1.5.6.2 **Recommendation.—** *For Facility Performance Category I — ILS glide paths, the nominal angular displacement sensitivity should correspond to a DDM of 0.0875 at an angular displacement below the glide path of 0.12* θ *with a tolerance of plus or minus 0.02* θ*. The upper and lower sectors should be as symmetrical as practicable within the limits specified in 3.1.5.6.1.*

3.1.5.6.3 For Facility Performance Category II — ILS glide paths, the angular displacement sensitivity shall be as symmetrical as practicable. 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;

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

3.1.5.6.4 For Facility Performance Category III — 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 of 0.12 θ with a tolerance of plus or minus 0.02 θ.

3.1.5.6.5 The DDM below the ILS glide path shall increase smoothly for decreasing angle until a value of 0.22 DDM is reached. This value shall be achieved at an angle not less than 0.30 θ above the horizontal. However, if it is achieved at an angle above 0.45 θ, the DDM value shall not be less than 0.22 at least down to 0.45 θ or to such lower angle, down to 0.30 θ, as required to safeguard the promulgated glide path intercept procedure.

Note.— The limits of glide path equipment adjustment are pictorially represented in Figure C-11 of Attachment C.

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

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

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

3.1.5.7 *Monitoring*

3.1.5.7.1 The automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the periods specified in 3.1.5.7.3.1 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 3.1.5.3, 3.1.5.4 and 3.1.5.5;

c) in 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 3.1.5.3, 3.1.5.4 and 3.1.5.5;

Note.— It is important to recognize that a frequency change resulting in a loss of the frequency difference specified in 3.1.5.2.1 may produce a hazardous condition. This problem is of greater operational significance for Categories II and III installations. As necessary, this problem can be dealt with through special monitoring provisions or highly reliable circuitry.

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;

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

Note 1.— The value of 0.7475 θ from horizontal is intended to ensure adequate obstacle clearance. This value was derived from other parameters of the glide path and monitor specification. Since the measuring accuracy to four significant figures is not intended, the value of 0.75 θ may be used as a monitor limit for this purpose. Guidance on obstacle clearance criteria is given in the Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) *(Doc 8168).*

Note 2.— Subparagraphs f) and g) are not intended to establish a requirement for a separate monitor to protect against deviation of the lower limits of the half-sector below 0.7475 θ *from horizontal.*

Note 3.— At glide path facilities where the selected nominal angular displacement sensitivity corresponds to an angle below the ILS glide path which is close to or at the maximum limits specified in 3.1.5.6, it may be necessary to adjust the monitor operating limits to protect against sector deviations below 0.7475 θ *from horizontal.*

Note 4.— Guidance material relating to the condition described in g) appears in Attachment C, 2.4.12.

3.1.5.7.2 **Recommendation.—** *Monitoring of the ILS glide path characteristics to smaller tolerances should be arranged in those cases where operational penalties would otherwise exist.*

3.1.5.7.3 The total period of radiation, including period(s) of zero radiation, outside the performance limits specified in 3.1.5.7.1 shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the ILS glide path.

3.1.5.7.3.1 The total period referred to under 3.1.5.7.3 shall not exceed under any circumstances:

6 seconds for Category I — ILS glide paths;

2 seconds for Categories II and III — ILS glide paths.

Note 1.— The total time periods specified are never-to-be-exceeded limits and are intended to protect aircraft in the final stages of approach against prolonged or repeated periods of ILS glide path guidance outside the monitor limits. For this reason, they include not only the initial period of outside tolerance operation but also the total of any or all periods of outside tolerance radiation, including periods of zero radiation, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent changeovers to glide path equipments or elements thereof.

Note 2.— From an operational point of view, the intention is that no guidance outside the monitor limits be radiated after the time periods given, and that no further attempts be made to restore service until a period in the order of 20 seconds has elapsed.

3.1.5.7.3.2 **Recommendation.—** *Where practicable, the total period specified under 3.1.5.7.3.1 for Categories II and III — ILS glide paths should not exceed 1 second.*

3.1.5.7.4 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 itself.

Note.— Guidance material on the design and operation of monitor systems is given in 2.1.7 of Attachment C.

3.1.5.8 *Integrity and continuity of service requirements*

3.1.5.8.1 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.

3.1.5.8.2 **Recommendation.—** *The probability of not radiating false guidance signals should not be less than $1 - 1.0 \times 10^{-7}$ in any one landing for Facility Performance Category I glide paths.*

3.1.5.8.3 The probability of not losing the radiated guidance signal shall be greater than $1 - 2 \times 10^{-6}$ in any period of 15 seconds for Facility Performance Categories II and III glide paths (equivalent to 2 000 hours mean time between outages).

3.1.5.8.4 **Recommendation.—** *The probability of not losing the radiated guidance signal should exceed 1 – 4 × 10^{-6} in any period of 15 seconds for Facility Performance Category I glide paths (equivalent to 1 000 hours mean time between outages).*

Note.— Guidance material on integrity and continuity of service is given in 2.8 of Attachment C.

3.1.6 Localizer and glide path frequency pairing

3.1.6.1 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 the provisions of Volume V, Chapter 4, 4.2:

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

3.1.6.1.1 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

Sequence number	*Localizer (MHz)*	*Glide path (MHz)*
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

3.1.6.2 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 3.1.6.1 or 3.1.6.1.1 as soon as practicable and may continue operating on their present assignments only until this reassignment can be effected.

3.1.6.3 Existing ILS localizers in the international service operating on frequencies ending in odd tenths of a megahertz shall not be assigned new frequencies ending in odd tenths plus one twentieth of a megahertz except where, by regional agreement, general use may be made of any of the channels listed in 3.1.6.1 (see Volume V, Chapter 4, 4.2).

3.1.7 VHF marker beacons

3.1.7.1 *General*

a) There shall be two marker beacons in each installation except as provided in 3.1.7.6.5. A third marker beacon may be added whenever, in the opinion of the Competent Authority, an additional beacon is required because of operational procedures at a particular site.

b) The marker beacons shall conform to the requirements prescribed in 3.1.7. When the installation comprises only two marker beacons, the requirements applicable to the middle marker and to the outer marker shall be complied with.

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

3.1.7.1.1 When a marker beacon is used in conjunction with the back course of a localizer, it shall conform with the marker beacon characteristics specified in 3.1.7.

3.1.7.1.2 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 3.1.7.5.1.

3.1.7.2 *Radio frequency*

3.1.7.2.1 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.

3.1.7.3 *Coverage*

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

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

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

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

3.1.7.3.2 The field strength at the limits of coverage specified in 3.1.7.3.1 shall be 1.5 millivolts per metre (minus 82 dBW/m^2). In addition, the field strength within the coverage area shall rise to at least 3.0 millivolts per metre (minus 76 dBW/m^2).

Note 1.— In the design of the ground antenna, it is advisable to ensure that an adequate rate of change of field strength is provided at the edges of coverage. It is also advisable to ensure that aircraft within the localizer course sector will receive visual indication.

Note 2.— Satisfactory operation of a typical airborne marker installation will be obtained if the sensitivity is so adjusted that visual indication will be obtained when the field strength is 1.5 millivolts per metre (minus 82 dBW/m^2).

3.1.7.4 *Modulation*

3.1.7.4.1 The modulation frequencies shall be as follows:

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

b) *middle marker:* 1 300 Hz;

c) *outer marker:* 400 Hz.

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.

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

3.1.7.5 *Identification*

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

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

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

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

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

3.1.7.6 *Siting*

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

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

Note 1.— It is intended that the inner marker pattern should intercept the downward extended straight portion of the nominal ILS glide path at the lowest decision height applicable in Category II operations.

Note 2.— Care must be exercised in siting the inner marker to avoid interference between the inner and middle markers. Details regarding the siting of inner markers are contained in Attachment C, 2.10.

3.1.7.6.1.2 **Recommendation.—** *If the radiation pattern is other than vertical, the equipment should 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 3.1.7.6.1.1.*

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

3.1.7.6.2.1 **Recommendation.—** *If the radiation pattern is vertical, the middle marker should be located 1 050 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.*

Note.— See Attachment C, 2.10, regarding the siting of inner and middle marker beacons.

3.1.7.6.2.2 **Recommendation.—** *If the radiation pattern is other than vertical, the equipment should 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 3.1.7.6.2.1.*

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

3.1.7.6.3.1 **Recommendation.—** *The outer marker should 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.*

3.1.7.6.4 **Recommendation.—** *If the radiation pattern is vertical, the outer marker should be not more than 75 m (250 ft) from the extended centre line of the runway. If the radiation pattern is other than vertical, the equipment should 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.*

3.1.7.6.5 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 Annex 15.

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

3.1.7.6.5.2 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.

3.1.7.6.5.3 The DME in 3.1.7.6.5 shall conform to the specification in 3.5.

3.1.7.7 *Monitoring*

3.1.7.7.1 Suitable equipment shall provide signals for the operation of an automatic monitor. The monitor shall transmit a warning to a control point if either of the following conditions arise:

a) failure of the modulation or keying;

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

3.1.7.7.2 **Recommendation.—** *For each marker beacon, suitable monitoring equipment should be provided which will indicate at the appropriate location a decrease of the modulation depth below 50 per cent.*

3.2 Specification for precision approach radar system

Note.— Slant distances are used throughout this specification.

3.2.1 The precision approach radar system shall comprise the following elements:

3.2.1.1 The precision approach radar element (PAR).

3.2.1.2 The surveillance radar element (SRE).

3.2.2 When 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”.

Note.— Provisions for the recording and retention of radar data are contained in Annex 11, Chapter 6.

3.2.3 The precision approach radar element (PAR)

3.2.3.1 *Coverage*

3.2.3.1.1 The PAR shall be capable of detecting and indicating the position of an aircraft of 15 m^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.

Note.— For guidance in determining the significance of the echoing areas of aircraft, the following table is included:

private flyer (single-engined): 5 to 10 m^2;

small twin-engined aircraft: from 15 m^2;

medium twin-engined aircraft: from 25 m^2;

four-engined aircraft: from 50 to 100 m^2.

3.2.3.2 *Siting*

3.2.3.2.1 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.

Note 1.— Paragraph 3.2.3.2.1 can be met by siting the equipment with a set-back from the touchdown, in the direction of the stop end of the runway, of 915 m (3 000 ft) or more, for an offset of 120 m (400 ft) from the runway centre line, or of 1 200 m (4 000 ft) or more, for an offset of 185 m (600 ft) when the equipment is aligned to scan plus or minus 10 degrees about the centre line of the runway. Alternatively, if the equipment is aligned to scan 15 degrees to one side and 5 degrees to the other side of the centre line of the runway, then the minimum set-back can be reduced to 685 m (2 250 ft) and 915 m (3 000 ft) for offsets of 120 m (400 ft) and 185 m (600 ft) respectively.

Note 2.— Diagrams illustrating the siting of PAR are given in Attachment C (Figures C-14 to C-17 inclusive).

3.2.3.3 *Accuracy*

3.2.3.3.1 *Azimuth accuracy.* Azimuth information shall be displayed in such a manner that left-right deviation from the on-course line shall be easily observable. 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. The equipment shall be so sited that the error at the touchdown shall not exceed 9 m (30 ft). 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. It shall be possible to resolve the positions of two aircraft which are at 1.2 degrees in azimuth of one another.

3.2.3.3.2 *Elevation accuracy.* Elevation information shall be displayed in such a manner that up-down deviation from the descent path for which the equipment is set shall be easily observable. 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. The equipment shall be so sited that the error at the touchdown shall not exceed 6 m (20 ft). 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. It shall be possible to resolve the positions of two aircraft that are at 0.6 degree in elevation of one another.

3.2.3.3.3 *Distance accuracy.* The error in indication of the distance from the touchdown shall not exceed 30 m (100 ft) plus 3 per cent of the distance from the touchdown. It shall be possible to resolve the positions of two aircraft which are at 120 m (400 ft) of one another on the same azimuth.

3.2.3.4 Information shall be made available to permit the position of the controlled aircraft to be established with respect to other aircraft and obstructions. Indications shall also permit appreciation of ground speed and rate of departure from or approach to the desired flight path.

3.2.3.5 Information shall be completely renewed at least once every second.

3.2.4 The surveillance radar element (SRE)

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

3.2.4.2 *Coverage*

3.2.4.2.1 The SRE shall be capable of detecting aircraft of 15 m^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 1.5 degrees above the horizontal plane of the antenna, extending from the antenna to 37 km (20 NM); by a vertical line at 37 km (20 NM) from the intersection with the 1.5-degree line up to 2 400 m (8 000 ft) above the level of the antenna; by a horizontal line at 2 400 m (8 000 ft) from 37 km (20 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 by a 20-degree line from the intersection with the 2 400 m (8 000 ft) line to the antenna.

3.2.4.2.2 **Recommendation.—** *Efforts should be made in development to increase the coverage on an aircraft of 15 m^2 echoing area to at least the volume obtained by amending 3.2.4.2.1 with the following substitutions:*

— for *1.5 degrees*, read *0.5 degree*;

— for *37 km (20 NM)*, read *46.3 km (25 NM)*;

— for *2 400 m (8 000 ft)*, read *3 000 m (10 000 ft)*;

— for *20 degrees*, read *30 degrees*.

Note.— A diagram illustrating the vertical coverage of SRE is given in Attachment C (Figure C-18).

3.2.4.3 *Accuracy*

3.2.4.3.1 *Azimuth accuracy.* The indication of position in azimuth shall be within plus or minus 2 degrees of the true position. It shall be possible to resolve the positions of two aircraft which are at 4 degrees of azimuth of one another.

3.2.4.3.2 *Distance accuracy.* The error in distance indication shall not exceed 5 per cent of true distance or 150 m (500 ft), whichever is the greater. It 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.

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

3.2.4.4 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 4 seconds.

3.2.4.5 **Recommendation.—** *Efforts should be made to reduce, as far as possible, the disturbance caused by ground echoes or echoes from clouds and precipitation.*

3.3 Specification for VHF omnidirectional radio range (VOR)

3.3.1 General

3.3.1.1 The VOR shall 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.

3.3.1.2 The VOR shall radiate a radio frequency carrier with which are associated two separate 30 Hz modulations. One of these modulations shall be such that its phase is independent of the azimuth of the point of observation (reference phase). 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.

3.3.1.3 The reference and variable phase modulations shall be in phase along the reference magnetic meridian through the station.

Note.— The reference and variable phase modulations are in phase when the maximum value of the sum of the radio frequency carrier and the sideband energy due to the variable phase modulation occurs at the same time as the highest instantaneous frequency of the reference phase modulation.

3.3.2 Radio frequency

3.3.2.1 The VOR shall operate in the band 111.975 MHz to 117.975 MHz except that frequencies in the band 108 MHz to 111.975 MHz may be used when, in accordance with the provisions of Volume V, Chapter 4, 4.2.1 and 4.2.3.1, the use of such frequencies is acceptable. The highest assignable frequency shall be 117.950 MHz. The channel separation shall be in increments of 50 kHz referred to the highest assignable frequency. 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.

3.3.2.2 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.

3.3.2.3 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.

3.3.3 Polarization and pattern accuracy

3.3.3.1 The emission from the VOR shall be horizontally polarized. The vertically polarized component of the radiation shall be as small as possible.

Note.— It is not possible at present to state quantitatively the maximum permissible magnitude of the vertically polarized component of the radiation from the VOR. (Information is provided in the Manual on Testing of Radio Navigation Aids *(Doc 8071) as to flight checks that can be carried out to determine the effects of vertical polarization on the bearing accuracy.)*

3.3.3.2 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.

3.3.4 Coverage

3.3.4.1 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.

3.3.4.2 **Recommendation.—** *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 should be 90 microvolts per metre or minus 107 dBW/m^2.*

Note.— Typical equivalent isotropically radiated powers (EIRPs) to achieve specified ranges are contained in 3.1 of Attachment C. The definition of EIRP is contained in 3.5.1.

3.3.5 Modulations of navigation signals

3.3.5.1 The radio frequency carrier as observed at any point in space shall be amplitude modulated by two signals as follows:

a) a subcarrier of 9 960 Hz of constant amplitude, frequency modulated at 30 Hz:

1) 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 (i.e. 15 to 17);

2) 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 (i.e. 15 to 17) 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;

b) a 30 Hz amplitude modulation component:

1) 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";

2) for the Doppler VOR, this component, of constant phase with relation to azimuth and constant amplitude, is radiated omnidirectionally and is termed the "reference phase".

3.3.5.2 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.

Note.— This requirement applies to the transmitted signal observed in the absence of multipath.

3.3.5.3 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. 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 5 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.

Note.— When modulation is measured during flight testing under strong dynamic multipath conditions, variations in the received modulation percentages are to be expected. Short-term variations beyond these values may be acceptable. The Manual on Testing of Radio Navigation Aids *(Doc 8071) contains additional information on the application of airborne modulation tolerances.*

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

3.3.5.5 The subcarrier modulation mid-frequency shall be 9 960 Hz within plus or minus 1 per cent.

3.3.5.6

a) For the conventional VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed 5 per cent.

b) For the Doppler VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed 40 per cent when measured at a point at least 300 m (1 000 ft) from the VOR.

3.3.5.7 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:

Subcarrier	*Level*
9 960 Hz	0 dB reference
2nd harmonic	–30 dB
3rd harmonic	–50 dB
4th harmonic and above	–60 dB

3.3.6 Voice and identification

3.3.6.1 If 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. The radiation on this channel shall be horizontally polarized.

3.3.6.2 The peak modulation depth of the carrier on the communication channel shall not be greater than 30 per cent.

3.3.6.3 The audio frequency characteristics of the speech channel shall be within 3 dB relative to the level at 1 000 Hz over the range 300 Hz to 3 000 Hz.

3.3.6.4 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. The identification signal radiation shall be horizontally polarized.

3.3.6.5 The identification signal shall employ the International Morse Code and consist of two or three letters. It shall be sent at a speed corresponding to approximately 7 words per minute. The signal shall be repeated at least once every 30 seconds and the modulation tone shall be 1 020 Hz within plus or minus 50 Hz.

3.3.6.5.1 **Recommendation.—** *The identification signal should be transmitted at least three times each 30 seconds, spaced equally within that time period. One of these identification signals may take the form of a voice identification.*

Note.— Where a VOR and DME are associated in accordance with 3.5.2.5, the identification provisions of 3.5.3.6.4 influence the VOR identification.

3.3.6.6 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 except 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.

3.3.6.6.1 **Recommendation.—** *If the VOR provides a simultaneous communication channel ground-to-air, the modulation depth of the code identification signal should be 5 plus or minus 1 per cent in order to provide a satisfactory voice quality.*

3.3.6.7 The transmission of speech shall not interfere in any way with the basic navigational function. When speech is being radiated, the code identification shall not be suppressed.

3.3.6.8 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 3.3.6.5, 3.3.6.6 and 3.3.6.7.

3.3.7 Monitoring

3.3.7.1 Suitable equipment located in the radiation field shall provide signals for the operation of an automatic monitor. 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) a change in excess of 1 degree at the monitor site of the bearing information transmitted by the VOR;

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.

3.3.7.2 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.

Note.— Guidance material on VOR appears in Attachment C, 3, and Attachment E.

3.3.8 Interference immunity performance for VOR receiving systems

3.3.8.1 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,

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 3.3.8.2.

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

3.3.8.2 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

Note 1.— The relationship is linear between adjacent points designated by the above frequencies.

Note 2.— Guidance material on immunity criteria to be used for the performance quoted in 3.3.8.1 and 3.3.8.2 is contained in Attachment C, 3.6.5.

3.4 Specification for non-directional radio beacon (NDB)

3.4.1 Definitions

Note.— In Attachment C, guidance is given on the meaning and application of rated coverage and effective coverage and on coverage of NDBs.

Average radius of rated coverage. The radius of a circle having the same area as the rated coverage.

Effective coverage. The area surrounding an NDB within which bearings can be obtained with an accuracy sufficient for the nature of the operation concerned.

Locator. An LF/MF NDB used as an aid to final approach.

Note.— A locator usually has an average radius of rated coverage of between 18.5 and 46.3 km (10 and 25 NM).

Rated coverage. 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.

Note.— The above definition is intended to establish a method of rating radio beacons on the normal coverage to be expected in the absence of sky wave transmission and/or anomalous propagation from the radio beacon concerned or interference from other LF/MF facilities, but taking into account the atmospheric noise in the geographical area concerned.

3.4.2 Coverage

3.4.2.1 **Recommendation.—** *The minimum value of field strength in the rated coverage of an NDB should be 70°microvolts per metre.*

Note 1.— Guidance on the field strengths required particularly in the latitudes between 30°N and 30°S is given in 6.1 of Attachment C, and the relevant ITU provisions are given in Chapter VIII, Article 35, Section IV, Part B of the Radio Regulations.

Note 2.— The selection of locations and times at which the field strength is measured is important in order to avoid abnormal results for the locality concerned; locations on air routes in the area around the beacon are operationally most significant.

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

Note 1.— In classifying radio beacons in areas where substantial variations in rated coverage may occur diurnally and seasonally, such variations should be taken into account.

Note 2.— Beacons having an average radius of rated coverage of between 46.3 and 278 km (25 and 150 NM) may be designated by the nearest multiple of 46.3 km (25 NM) to the average radius of rated coverage, and beacons of rated coverage over 278 km (150 NM) to the nearest multiple of 92.7 km (50 NM).

3.4.2.3 **Recommendation.—** *Where the rated coverage of an NDB is materially different in various operationally significant sectors, its classification should be expressed in terms of the average radius of rated coverage and the angular limits of each sector as follows:*

Radius of coverage of sector/angular limits of sector expressed as magnetic bearing clockwise from the beacon.

Where it is desirable to classify an NDB in such a manner, the number of sectors should be kept to a minimum and preferably should not exceed two.

Note.— The average radius of a given sector of the rated coverage is equal to the radius of the corresponding circle-sector of the same area. Example:

150/210° – 30°
100/30° – 210°.

3.4.3 Limitations in radiated power

The power radiated from an NDB shall not exceed by more than 2 dB that 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.

3.4.4 Radio frequencies

3.4.4.1 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.

3.4.4.2 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.

3.4.4.3 **Recommendation.—** *Where two locators are used as supplements to an ILS, the frequency separation between the carriers of the two should be not less than 15 kHz to ensure 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.*

3.4.4.4 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.

Note.— Additional guidance on the operation of locator beacons on common frequency channels is contained in Volume V, Chapter 3, 3.2.2.

3.4.5 Identification

3.4.5.1 Each NDB shall be individually identified by a two- or three-letter International Morse Code group transmitted at a rate corresponding to approximately 7 words per minute.

3.4.5.2 The complete identification shall be transmitted at least once every 30 seconds, except where the beacon identification is effected by on/off keying of the carrier. In this latter case, the identification shall be at approximately 1-minute intervals, except that a shorter interval may be used at particular NDB stations where this is found to be operationally desirable.

3.4.5.2.1 **Recommendation.—** *Except for those cases where the beacon identification is effected by on/off keying of the carrier, the identification signal should be transmitted at least three times each 30 seconds, spaced equally within that time period.*

3.4.5.3 For NDBs with an average radius of rated coverage of 92.7 km (50 NM) or less that are primarily approach and holding aids in the vicinity of an aerodrome, the identification shall be transmitted at least three times each 30 seconds, spaced equally within that time period.

3.4.5.4 The frequency of the modulating tone used for identification shall be 1 020 Hz plus or minus 50 Hz or 400 Hz plus or minus 25 Hz.

Note.— Determination of the figure to be used would be made regionally, in the light of the considerations contained in Attachment C, 6.5.

3.4.6 Characteristics of emissions

Note.— The following specifications are not intended to preclude employment of modulations or types of modulations that may be utilized in NDBs in addition to those specified for identification, including simultaneous identification and voice modulation, provided that these additional modulations do not materially affect the operational performance of the NDBs in conjunction with currently used airborne direction finders, and provided their use does not cause harmful interference to other NDB services.

3.4.6.1 Except as provided in 3.4.6.1.1, all NDBs shall radiate an uninterrupted carrier and be identified by on/off keying of an amplitude modulating tone (NON/A2A).

3.4.6.1.1 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/off keying of the unmodulated carrier (NON/A1A) if they are in areas of high beacon density and/or where the required rated coverage is not practicable of achievement because of:

a) radio interference from radio stations;

b) high atmospheric noise;

c) local conditions.

Note.— In selecting the types of emission, the possibility of confusion, arising from an aircraft tuning from a NON/A2A facility to a NON/A1A facility without changing the radio compass from "MCW" to "CW" operation, will need to be kept in mind.

3.4.6.2 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.

3.4.6.3 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.

Note 1.— The foregoing requirement necessitates as high a percentage modulation as practicable, together with maintenance of an adequate radiated carrier power during identification.

Note 2.— With a direction-finder pass band of plus or minus 3 kHz about the carrier, a signal to noise ratio of 6 dB at the limit of rated coverage will, in general, meet the foregoing requirement.

Note 3.— Some considerations with respect to modulation depth are contained in Attachment C, 6.4.

3.4.6.4 **Recommendation.—** *The carrier power of an NDB with NON/A2A emissions should 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.*

3.4.6.5 Unwanted audio frequency modulations shall total less than 5 per cent of the amplitude of the carrier.

Note.— Reliable performance of airborne automatic direction-finding equipment (ADF) may be seriously prejudiced if the beacon emission contains modulation by an audio frequency equal or close to the loop switching frequency or its second harmonic. The loop switching frequencies in currently used equipment lie between 30 Hz and 120 Hz.

3.4.6.6 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.

Note.— Article S3 of the ITU Radio Regulations contains the general provisions with respect to technical characteristics of equipment and emissions. The Radio Regulations contain specific provisions relating to necessary bandwidth, frequency tolerance, spurious emissions and classification of emissions (see Appendices APS1, APS2 and APS3).

3.4.7 Siting of locators

3.4.7.1 **Recommendation.—** *Where locators are used as a supplement to the ILS, they should be located at the sites of the outer and middle marker beacons. Where only one locator is used as a supplement to the ILS, preference should be given to location at the site of the outer marker beacon. 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 should be selected, taking into account the relevant obstacle clearance provisions of the* PANS-OPS *(Doc 8168).*

3.4.7.2 **Recommendation.—** *Where locators are installed at both the middle and outer marker positions, they should 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.*

3.4.8 Monitoring

3.4.8.1 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;

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

3.4.8.2 **Recommendation.—** *When an NDB is operated from a power source having a frequency which is close to airborne ADF equipment switching frequencies, and where the design of the NDB is such that the power supply frequency is likely to appear as a modulation product on the emission, the means of monitoring should be capable of detecting such power supply modulation on the carrier in excess of 5 per cent.*

3.4.8.3 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 3.4.8.1 a), b) and c).

3.4.8.4 **Recommendation.—** *During the hours of service of an NDB other than a locator, the means of monitoring should provide for a continuous check on the functioning of the NDB as prescribed in 3.4.8.1 a), b) and c).*

Note.— Guidance material on the testing of NDBs is contained in 6.6 of Attachment C.

3.5 Specification for UHF distance measuring equipment (DME)

Note.— In the following section, provision is made for two types of DME facility: DME/N for general application, and DME/P as outlined in 3.11.3.

3.5.1 Definitions

Control motion noise (CMN). 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. (See 3.11.)

DME dead time. A period immediately following the decoding of a valid interrogation during which a received interrogation will not cause a reply to be generated.

Note.— Dead time is intended to prevent the transponder from replying to echoes resulting from multipath effects.

DME/N. Distance measuring equipment, primarily serving operational needs of en-route or TMA navigation, where the “N” stands for narrow spectrum characteristics.

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

Equivalent isotropically radiated power (EIRP). 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).

Final approach (FA) mode. The condition of DME/P operation which supports flight operations in the final approach and runway regions.

Initial approach (IA) mode. The condition of DME/P operation which supports those flight operations outside the final approach region and which is interoperable with DME/N.

Key down time. The time during which a dot or dash of a Morse character is being transmitted.

MLS approach reference datum. A point on the minimum glide path at a specified height above the threshold. (See 3.11.)

MLS datum point. The point on the runway centre line closest to the phase centre of the approach elevation antenna. (See 3.11.)

Mode W, X, Y, Z. *A method of coding the DME transmissions by time spacing pulses of a pulse pair, so that each frequency can be used more than once.*

Partial rise time. The time as measured between the 5 and 30 per cent amplitude points on the leading edge of the pulse envelope, i.e. between points h and i on Figures 3-1 and 3-2.

Path following error (PFE). That portion of the guidance signal error which could cause aircraft displacement from the desired course and/or glide path. (See 3.11.)

Pulse amplitude. The maximum voltage of the pulse envelope, i.e. A in Figure 3-1.

Pulse decay time. The time as measured between the 90 and 10 per cent amplitude points on the trailing edge of the pulse envelope, i.e. between points e and g on Figure 3-1.

Pulse code. The method of differentiating between W, X, Y and Z modes and between FA and IA modes.

Pulse duration. The time interval between the 50 per cent amplitude point on leading and trailing edges of the pulse envelope, i.e. between points b and f on Figure 3-1.

Pulse rise time. The time as measured between the 10 and 90 per cent amplitude points on the leading edge of the pulse envelope, i.e. between points a and c on Figure 3-1.

Reply efficiency. The ratio of replies transmitted by the transponder to the total of received valid interrogations.

Search. 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.

System efficiency. The ratio of valid replies processed by the interrogator to the total of its own interrogations.

Track. 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.

Transmission rate. The average number of pulse pairs transmitted from the transponder per second.

Virtual origin. The point at which the straight line through the 30 per cent and 5 per cent amplitude points on the pulse leading edge intersects the 0 per cent amplitude axis (see Figure 3-2).

3.5.2 General

3.5.2.1 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.

3.5.2.2 The system shall comprise two basic components, one fitted in the aircraft, the other installed on the ground. The aircraft component shall be referred to as the interrogator and the ground component as the transponder.

3.5.2.3 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.

3.5.2.4 DME/P shall have two operating modes, IA and FA.

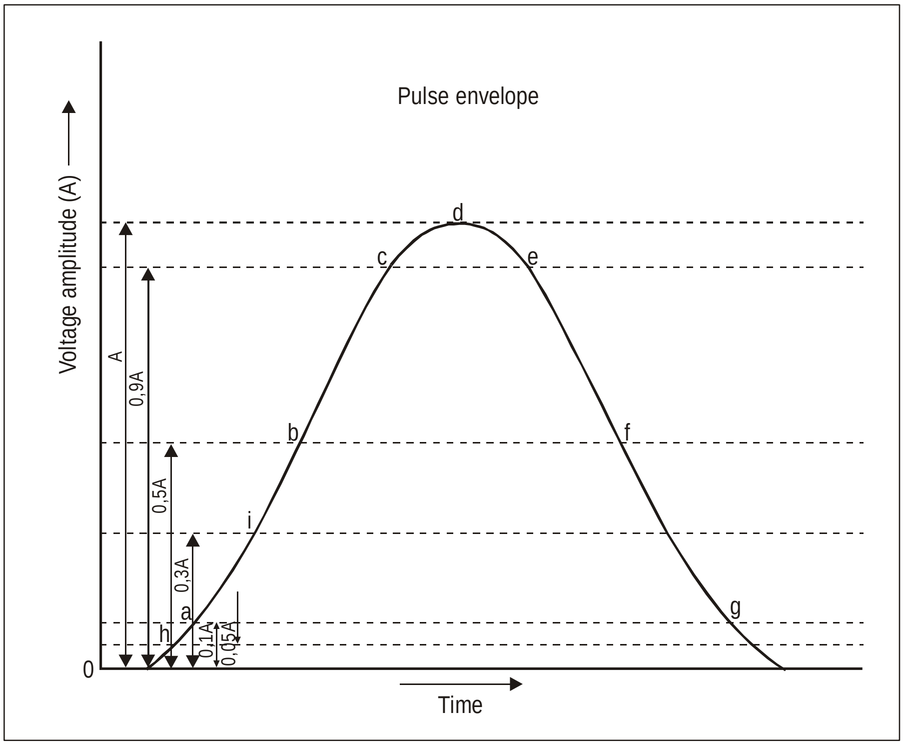

Figure 3-1

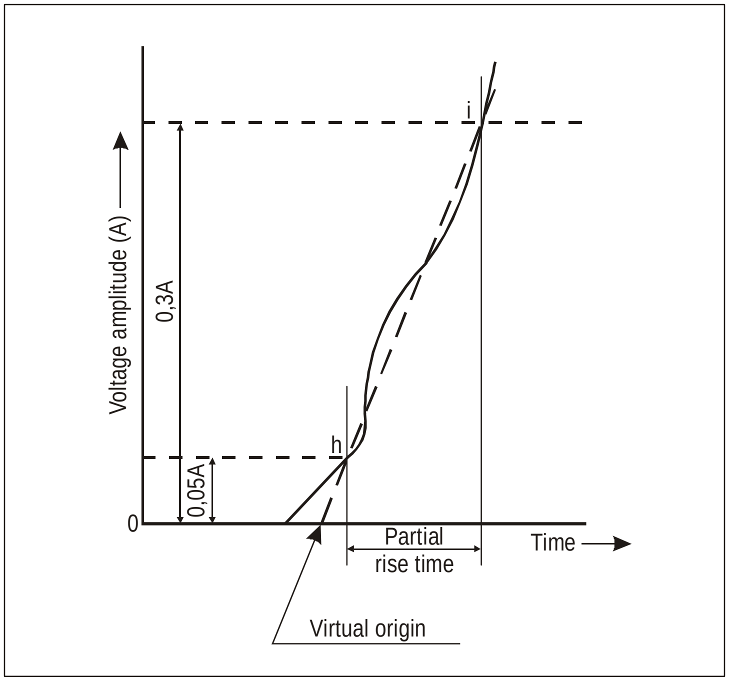

Figure 3-2

3.5.2.5 When a DME is associated with an ILS, MLS or VOR for the purpose of constituting a single facility, they shall:

a) be operated on a standard frequency pairing in accordance with 3.5.3.3.4;

b) be collocated within the limits prescribed for associated facilities in 3.5.2.6; and

c) comply with the identification provisions of 3.5.3.6.4.

3.5.2.6 *Collocation limits for a DME facility associated with an ILS, MLS or VOR facility*

3.5.2.6.1 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);

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).

3.5.2.6.2 *Association of DME with ILS*

Note.— Attachment C, 2.11 gives guidance on the association of DME with ILS.

3.5.2.6.3 *Association of DME with MLS*

3.5.2.6.3.1 **Recommendation.—** *If a DME/P is used to provide ranging information, it should be sited as close as possible to the MLS azimuth facility.*

Note.— Attachment G, 5 and Attachment C, 7.1.6 give guidance on siting of DME with MLS. This guidance sets forth, in particular, appropriate steps to be taken to prevent different zero range indication if DME/P associated with MLS and DME/N associated with ILS serve the same runway.

3.5.2.7 The Standards in 3.5.3, 3.5.4 and 3.5.5 denoted by ‡ shall apply only to DME equipment first installed after 1 January 1989.

3.5.3 System characteristics

3.5.3.1 *Performance*

3.5.3.1.1 *Range.* 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.

3.5.3.1.2 *Coverage*

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

3.5.3.1.2.2 When associated with either an ILS or an MLS, DME/N coverage shall be at least that of the respective ILS or of the MLS azimuth angle guidance coverage sectors.

3.5.3.1.2.3 DME/P coverage shall be at least that provided by the MLS azimuth angle guidance coverage sectors.

Note.— This is not intended to specify the operational range and coverage to which the system may be used; spacing of facilities already installed may limit the range in certain areas.

3.5.3.1.3 *Accuracy*

3.5.3.1.3.1 *System accuracy.* The accuracy standards specified in 3.5.3.1.4, 3.5.4.5 and 3.5.5.4 shall be met on a 95 per cent probability basis.

3.5.3.1.4 *DME/P accuracy*

Note 1.— In the following, two accuracy standards, 1 and 2, are stated for the DME/P to accommodate a variety of applications.

Note 2.— Guidance on accuracy standards is given in Attachment C, 7.3.2.

3.5.3.1.4.1 *Error components.* 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. 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.

Note.— Specified error limits at a point are to be applied over a flight path that includes that point. Information on the interpretation of DME/P errors and the measurement of those errors over an interval appropriate for flight inspection is provided in Attachment C, 7.3.6.1.

3.5.3.1.4.2 Errors on the extended runway centre line shall not exceed the values given in Table B at the end of this chapter.

3.5.3.1.4.3 In the approach sector, away from the extended runway centre line, the allowable PFE for both standard 1 and standard 2 shall be permitted to increase linearly with angle up to plus or minus 40 degrees MLS azimuth angle where the permitted error is 1.5 times that on the extended runway centre line at the same distance. The allowable CMN shall not increase with angle. There shall be no degradation of either PFE or CMN with elevation angle.

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

3.5.3.3 *Channelling*

3.5.3.3.1 DME operating channels shall be formed by pairing interrogation and reply frequencies and by pulse coding on the paired frequencies.

3.5.3.3.2 *Pulse coding.* DME/P channels shall have two different interrogation pulse codes as shown in the table in 3.5.4.4.1. One shall be used in the initial approach (IA) mode; the other shall be used in the final approach (FA) mode.

3.5.3.3.3 DME operating channels shall be chosen from Table A (located at the end of this chapter), of 352 channels in which the channel numbers, frequencies, and pulse codes are assigned.

3.5.3.3.4 *Channel pairing.* When 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 and/or an MLS angle facility in the 5 031.0 MHz to 5 090.7 MHz frequency band, the DME operating channel shall be paired with the VHF channel and/or MLS angle frequency as given in Table A.

Note.— There may be instances when a DME channel will be paired with both the ILS frequency and an MLS channel (see Volume V, Chapter 4, 4.3).

3.5.3.4 *Interrogation pulse repetition frequency*

Note.— If the interrogator operates on more than one channel in one second, the following specifications apply to the sum of interrogations on all channels.

3.5.3.4.1 *DME/N.* 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.

3.5.3.4.2 *DME/N.* 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.

3.5.3.4.3 *DME/N.* **Recommendation.—** *After 15 000 pairs of pulses have been transmitted without acquiring indication of distance, the PRF should not exceed 60 pairs of pulses per second thereafter, until a change in operating channel is made or successful search is completed.*

‡3.5.3.4.4 *DME/N.* When, 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.

3.5.3.4.5 *DME/P.* The interrogator pulse repetition frequency shall not exceed the following number of pulse pairs per second:

a)	search	40
b)	aircraft on the ground	5
c)	initial approach mode track	16
d)	final approach mode track	40

Note 1.— A pulse repetition frequency (PRF) of 5 pulse pairs per second for aircraft on the ground may be exceeded if the *aircraft requires accurate range information.*

Note 2.— It is intended that all PRF changes be achieved by automatic means.

3.5.3.5 *Aircraft handling capacity of the system*

3.5.3.5.1 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.

3.5.3.5.2 **Recommendation.—** *Where the peak traffic in an area exceeds 100 aircraft, the transponder should be capable of handling that peak traffic.*

Note.— Guidance material on aircraft handling capacity will be found in Attachment C, 7.1.5.

3.5.3.6 *Transponder identification*

3.5.3.6.1 All transponders shall transmit an identification signal in one of the following forms as required by 3.5.3.6.5:

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

b) an "associated" signal which can be used for transponders specifically associated with a VHF navigation or an MLS angle guidance facility which itself transmits an identification signal.

Note.— An MLS angle guidance facility provides its identification as a digital word transmitted on the data channel into the approach and back azimuth coverage regions as specified in 3.11.4.6.2.1.

3.5.3.6.2 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 3.5.3.6.2.2. These pulses shall have similar characteristics to the other pulses of the reply signals.

‡3.5.3.6.2.1 *DME/N.* Reply pulses shall be transmitted between key down times.

3.5.3.6.2.2 *DME/N.* **Recommendation.—** *If it is desired to preserve a constant duty cycle, an equalizing pair of pulses, having the same characteristics as the identification pulse pairs, should be transmitted 100 microseconds plus or minus 10 microseconds after each identity pair.*

3.5.3.6.2.3 *DME/P.* Reply pulses shall be transmitted between key down times.

3.5.3.6.2.4 For the DME/P transponder, reply pulse pairs to valid FA mode interrogations shall also be transmitted during key down times and have priority over identification pulse pairs.

3.5.3.6.2.5 The DME/P transponder shall not employ the equalizing pair of pulses of 3.5.3.6.2.2.

3.5.3.6.3 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 6 words per minute; and

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 5 seconds per identification code group. The dots shall be a time duration of 0.1 second to 0.160 second. The dashes shall be typically 3 times the duration of the dots.

The duration between dots and/or dashes shall be equal to that of one dot plus or minus 10 per cent. The time duration between letters or numerals shall not be less than three dots. The total period for transmission of an identification code group shall not exceed 10 seconds.

Note.— The tone identification signal is transmitted at a repetition rate of 1 350 pps. This frequency may be used directly in the airborne equipment as an aural output for the pilot, or other frequencies may be generated at the option of the interrogator designer (see 3.5.3.6.2).

3.5.3.6.4 The characteristics of the "associated" signal shall be as follows:

a) when associated with a VHF or an MLS angle facility, the identification shall be transmitted in the form of dots and dashes (International Morse Code) as in 3.5.3.6.3 and shall be synchronized with the VHF facility identification code;

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 and MLS angle facility identification, where these are provided, transmitted during the remaining periods;

c) for a DME transponder associated with an MLS, the identification shall be the last three letters of the MLS angle facility identification specified in 3.11.4.6.2.1.

3.5.3.6.5 *Identification implementation*

3.5.3.6.5.1 The "independent" identification code shall be employed wherever a transponder is not specifically associated with a VHF navigational facility or an MLS facility.

3.5.3.6.5.2 Wherever a transponder is specifically associated with a VHF navigational facility or an MLS facility, identification shall be provided by the "associated" code.

3.5.3.6.5.3 When voice communications are being radiated on an associated VHF navigational facility, an "associated" signal from the transponder shall not be suppressed.

3.5.3.7 *DME/P mode transition*

3.5.3.7.1 The DME/P interrogator for standard 1 accuracy shall change from IA mode track to FA mode track at 13 km (7 NM) from the transponder when approaching the transponder, or any other situation when within 13 km (7 NM).

3.5.3.7.2 For standard 1 accuracy, the transition from IA mode to FA mode track operation may be initiated within 14.8 m (8 NM) from the transponder. Outside 14.8 km (8 NM), the interrogator shall not interrogate in the FA mode.

Note.— Paragraph 3.5.3.7.1 does not apply if the transponder is a DME/N or if the DME/P transponder FA mode is inoperative.

3.5.3.8 *System efficiency.* The DME/P system accuracy of 3.5.3.1.4 shall be achieved with a system efficiency of 50 per cent or more.

3.5.4 Detailed technical characteristics of transponder and associated monitor

3.5.4.1 *Transmitter*

3.5.4.1.1 *Frequency of operation.* The transponder shall transmit on the reply frequency appropriate to the assigned DME channel (see 3.5.3.3.3).

3.5.4.1.2 *Frequency stability.* The radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

3.5.4.1.3 *Pulse shape and spectrum.* The following shall apply to all radiated pulses:

a) *Pulse rise time.*

   1) *DME/N.* Pulse rise time shall not exceed 3 microseconds.

   2) *DME/P.* Pulse rise time shall not exceed 1.6 microseconds. For the FA mode, the pulse shall have a partial rise time of 0.25 plus or minus 0.05 microsecond. With respect to the FA mode and accuracy standard 1, the slope of the pulse in the partial rise time shall not vary by more than plus or minus 20 per cent. For accuracy standard 2, the slope shall not vary by more than plus or minus 10 per cent.

   3) *DME/P.* **Recommendation.—** *Pulse rise time should not exceed 1.2 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) For DME/N and DME/P: 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 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 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.

   Note.— Guidance material relating to the pulse spectrum measurement is provided in Document EUROCAE ED-57 (including Amendment No. 1).

f) 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. Initiation of the turn-on process shall not commence sooner than 1 microsecond prior to the virtual origin.

Note 1.— The time "during the pulse" encompasses the total interval from the beginning of pulse transmission to its end. For practical reasons, this interval may be measured between the 5 per cent points on the leading and trailing edges of the pulse envelope.

Note 2.— The power contained in the frequency bands specified in 3.5.4.1.3 e) is the average power during the pulse. Average power in a given frequency band is the energy contained in this frequency band divided by the time of pulse transmission according to Note 1.

3.5.4.1.4 *Pulse spacing*

3.5.4.1.4.1 The spacing of the constituent pulses of transmitted pulse pairs shall be as given in the table in 3.5.4.4.1.

3.5.4.1.4.2 *DME/N.* The tolerance on the pulse spacing shall be plus or minus 0.25 microsecond.

3.5.4.1.4.3 *DME/N.* **Recommendation.—** *The tolerance on the DME/N pulse spacing should be plus or minus 0.10 microsecond.*

3.5.4.1.4.4 *DME/P.* The tolerance on the pulse spacing shall be plus or minus 0.10 microsecond.

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

3.5.4.1.5 *Peak power output*

3.5.4.1.5.1 *DME/N.* **Recommendation.—** *The peak EIRP should not be less than that required to ensure a peak pulse power density of approximately minus 83 dBW/m^2 at the maximum specified service range and level.*

‡3.5.4.1.5.2 *DME/N.* 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 3.5.3.1.2.

Note.— Although the Standard in 3.5.4.1.5.2 implies an improved interrogator receiver sensitivity, it is intended that the power density specified in 3.5.4.1.5.1 be available at the maximum specified service range and level.

3.5.4.1.5.3 *DME/P.* The peak equivalent isotropically radiated power shall not be less than that required to ensure the following peak pulse power densities under all operational weather conditions:

a) minus 89 dBW/m^2 at any point within the coverage specified in 3.5.3.1.2 at ranges greater than 13 km (7 NM) from the transponder antenna;

b) minus 75 dBW/m^2 at any point within the coverage specified in 3.5.3.1.2 at ranges less than 13 km (7 NM) from the transponder antenna;

c) minus 70 dBW/m^2 at the MLS approach reference datum;

d) minus 79 dBW/m^2 at 2.5 m (8 ft) above the runway surface, at the MLS datum point, or at the farthest point on the runway centre line which is in line of sight of the DME transponder antenna.

Note.— Guidance material relating to the EIRP may be found in Attachment C, 7.2.1 and 7.3.8.

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

3.5.4.1.5.5 **Recommendation.—** *The reply capability of the transmitter should be such that the transponder should 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).*

Note.— Guidance on the relationship between number of aircraft and transmission rate is given in Attachment C, 7.1.5.

3.5.4.1.5.6 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. The minimum transmission rate shall be as close as practicable to 700 pulse pairs per second. For DME/P, in no case shall it exceed 1 200 pulse pairs per second.

Note.— Operating DME transponders with quiescent transmission rates close to 700 pulse pairs per second will minimize the effects of pulse interference, particularly to other aviation services such as GNSS.

3.5.4.1.6 *Spurious radiation.* During intervals between transmission of individual pulses, the spurious power received and measured in a receiver having the same characteristics as a transponder receiver, but tuned to any DME interrogation or reply frequency, shall 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. This provision refers to all spurious transmissions, including modulator and electrical interference.

‡3.5.4.1.6.1 *DME/N.* The spurious power level specified in 3.5.4.1.6 shall be more than 80 dB below the peak pulse power level.

3.5.4.1.6.2 *DME/P.* The spurious power level specified in 3.5.4.1.6 shall be more than 80 dB below the peak pulse power level.

3.5.4.1.6.3 *Out-of-band spurious radiation.* At all frequencies from 10 to 1 800 MHz, but excluding the band of frequencies from 960 to 1 215 MHz, the spurious output of the DME transponder transmitter shall not exceed minus 40 dBm in any one kHz of receiver bandwidth.

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

3.5.4.2 *Receiver*

3.5.4.2.1 *Frequency of operation.* The receiver centre frequency shall be the interrogation frequency appropriate to the assigned DME operating channel (see 3.5.3.3.3).

3.5.4.2.2 *Frequency stability.* The centre frequency of the receiver shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

3.5.4.2.3 *Transponder sensitivity*

3.5.4.2.3.1 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);

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

c) minus 86 dBW/m^2 for DME/P IA mode;

d) minus 75 dBW/m^2 for DME/P FA mode.

3.5.4.2.3.2 The minimum power densities specified in 3.5.4.2.3.1 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;

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

‡3.5.4.2.3.3 *DME/N dynamic range.* 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 3.5.4.2.3.1 up to a maximum of minus 22 dBW/m^2 when installed with ILS or MLS and minus 35 dBW/m^2 when installed for other applications.

3.5.4.2.3.4 *DME/P dynamic range.* 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 3.5.4.2.3.1 up to a maximum of minus 22 dBW/m^2.

3.5.4.2.3.5 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.

‡3.5.4.2.3.6 *DME/N.* 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.

3.5.4.2.3.7 *DME/P.* 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.

3.5.4.2.4 *Load limiting*

3.5.4.2.4.1 *DME/N.* **Recommendation.—** *When transponder loading exceeds 90 per cent of the maximum transmission rate, the receiver sensitivity should 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 should be at least 50 dB.)*

3.5.4.2.4.2 *DME/P.* To prevent transponder overloading the transponder shall automatically limit its replies, so as to ensure that the maximum transmission rate is not exceeded. If the receiver sensitivity reduction is implemented to meet this requirement, it shall be applied to the IA mode only and shall not affect the FA mode.

3.5.4.2.5 *Noise.* When the receiver is interrogated at the power densities specified in 3.5.4.2.3.1 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.

3.5.4.2.6 *Bandwidth*

3.5.4.2.6.1 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.

3.5.4.2.6.2 *DME/N.* The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3.

3.5.4.2.6.3 *DME/P — IA mode.* The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3. The 12 dB bandwidth shall not exceed 2 MHz and the 60 dB bandwidth shall not exceed 10 MHz.

3.5.4.2.6.4 *DME/P — FA mode.* The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3. The 12 dB bandwidth shall not exceed 6 MHz and the 60 dB bandwidth shall not exceed 20 MHz.

3.5.4.2.6.5 Signals greater than 900 kHz removed from the desired channel nominal frequency and having power densities up to the values specified in 3.5.4.2.3.3 for DME/N and 3.5.4.2.3.4 for DME/P 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.

3.5.4.2.7 *Recovery time.* Within 8 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. This requirement shall be met with echo suppression circuits, if any, rendered inoperative. The 8 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 3.5.5.1.3.

3.5.4.2.8 *Spurious radiations.* Radiation from any part of the receiver or allied circuits shall meet the requirements stated in 3.5.4.1.6.

3.5.4.2.9 *CW and echo suppression*

Recommendation.— *CW and echo suppression should be adequate for the sites at which the transponders will be used.*

Note.— In this connection, echoes mean undesired signals caused by multipath transmission (reflections, etc.).

3.5.4.2.10 *Protection against interference*

Recommendation.— *Protection against interference outside the DME frequency band should be adequate for the sites at which the transponders will be used.*

3.5.4.3 *Decoding*

3.5.4.3.1 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 3.5.5.1.3 and 3.5.5.1.4.

3.5.4.3.2 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.

‡3.5.4.3.3 *DME/N — Decoder rejection.* An interrogation pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to the value specified in 3.5.4.2.3.3 shall be rejected such that the transmission rate does not exceed the value obtained when interrogations are absent.

3.5.4.3.4 *DME/P — Decoder rejection.* An interrogation pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to the value specified in 3.5.4.2.3.4 shall be rejected such that the transmission rate does not exceed the value obtained when interrogations are absent.

3.5.4.4 *Time delay*

3.5.4.4.1 When a DME is associated only with a VHF facility, the time delay shall 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. This delay shall be consistent with the following table, when it is desired that aircraft interrogators are to indicate 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	–

Note 1.— W and X are multiplexed on the same frequency.

Note 2.— Z and Y are multiplexed on the same frequency.

3.5.4.4.2 When a DME is associated with an MLS angle facility, the time delay shall be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pair and the half voltage point on the leading edge of the first constituent pulse of the reply transmission. This delay shall be 50 microseconds for mode X channels and 56 microseconds for mode Y channels, when it is desired that aircraft interrogators are to indicate distance from the transponder site.

3.5.4.4.2.1 For DME/P transponders, no time delay adjustment shall be permitted.

3.5.4.4.3 **Recommendation.—** *For the DME/N the transponder time delay should be capable of being set to an appropriate value between the nominal value of the time delay minus 15 microseconds and the nominal value of the time delay, to permit aircraft interrogators to indicate zero distance at a specific point remote from the transponder site.*

Note.— Modes not allowing for the full 15 microseconds range of adjustment in transponder time delay may only be adjustable to the limits given by the transponder circuit delay and recovery time.

‡3.5.4.4.3.1 *DME/N.* The time delay shall be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pair and the half voltage point on the leading edge of the first constituent pulse of the reply transmission.

3.5.4.4.3.2 *DME/P — IA mode.* The time delay shall be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pulse pair to the half voltage point on the leading edge of the first constituent pulse of the reply pulse pair.

3.5.4.4.3.3 *DME/P — FA mode.* The time delay shall be the interval from the virtual origin of the first constituent pulse of the interrogation pulse pair to the virtual origin of the first constituent pulse of the reply pulse pair. The time of arrival measurement points shall be within the partial rise time of the first constituent pulse of the pulse pair in each case.

3.5.4.4.4 *DME/N.* **Recommendation.—** *Transponders should be sited as near to the point at which zero indication is required as is practicable.*

Note 1.— It is desirable that the radius of the sphere at the surface of which zero indication is given be kept as small as possible in order to keep the zone of ambiguity to a minimum.

Note 2.— Guidance material on siting DME with MLS is provided in 7.1.6 of Attachment C and 5 of Attachment G. This guidance material sets forth, in particular, appropriate steps to be taken to prevent different zero range indication if DME/P associated with MLS and DME/N associated with ILS serve the same runway.

3.5.4.5 *Accuracy*

3.5.4.5.1 *DME/N.* The transponder shall not contribute more than plus or minus 1 microsecond (150 m (500 ft)) to the overall system error.

3.5.4.5.1.1 *DME/N.* **Recommendation.—** *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 should be not greater than plus or minus 340 m (0.183 NM) plus 1.25 per cent of distance measure.*

Note.— This error contribution limit includes errors from all causes except the airborne equipment, and assumes that the airborne equipment measures time delay based on the first constituent pulse of a pulse pair.

‡3.5.4.5.1.2 *DME/N.* 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.

Note.— This error contribution limit includes errors from all causes except the airborne equipment, and assumes that the airborne equipment measures time delay based on the first constituent pulse of a pulse pair.

‡3.5.4.5.2 *DME/N.* 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.

3.5.4.5.3 *DME/P — FA mode*

3.5.4.5.3.1 *Accuracy standard 1.* The transponder shall not contribute more than plus or minus 10 m (plus or minus 33 ft) PFE and plus or minus 8 m (plus or minus 26 ft) CMN to the overall system error.

3.5.4.5.3.2 *Accuracy standard 2.* The transponder shall not contribute more than plus or minus 5 m (plus or minus 16 ft) PFE and plus or minus 5 m (plus or minus 16 ft) CMN to the overall system error.

3.5.4.5.4 *DME/P — IA mode.* The transponder shall not contribute more than plus or minus 15 m (plus or minus 50 ft) PFE and plus or minus 10 m (plus or minus 33 ft) CMN to the overall system error.

3.5.4.5.5 **Recommendation.—** *When a DME is associated with an MLS angle facility, the above accuracy should include the error introduced by the first pulse detection due to the pulse spacing tolerances.*

3.5.4.6 *Efficiency*

3.5.4.6.1 The transponder reply efficiency shall be at least 70 per cent for DME/N and DME/P (IA mode) and 80 per cent for DME/P (FA mode) at all values of transponder loading up to the loading corresponding to 3.5.3.5 and at the minimum sensitivity level specified in 3.5.4.2.3.1 and 3.5.4.2.3.5.

Note.— When considering the transponder reply efficiency value, account is to be taken of the DME dead time and of the loading introduced by the monitoring function.

3.5.4.6.2 *Transponder dead time.* The transponder shall be rendered inoperative for a period normally not to exceed 60 microseconds after a valid interrogation decode has occurred. 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 and DME/P IA mode.

3.5.4.6.2.1 In DME/P the IA mode dead time shall not blank the FA mode channel and vice versa.

3.5.4.7 *Monitoring and control*

3.5.4.7.1 Means shall be provided at each transponder site for the automatic monitoring and control of the transponder in use.

3.5.4.7.2 *DME/N monitoring action*

3.5.4.7.2.1 In the event that any of the conditions specified in 3.5.4.7.2.2 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.

3.5.4.7.2.2 The monitor shall cause the actions specified in 3.5.4.7.2.1 if:

a) the transponder delay differs from the assigned value by 1 microsecond (150 m (500 ft)) or more;

‡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.

3.5.4.7.2.3 **Recommendation.—** *The monitor should cause the actions specified in 3.5.4.7.2.1 if the spacing between the first and second pulse of the transponder pulse pair differs from the nominal value specified in the table following 3.5.4.4.1 by 1 microsecond or more.*

3.5.4.7.2.4 **Recommendation.—** *The monitor should 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 3.5.4.1.4 by 1 microsecond or more;

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).

3.5.4.7.2.5 Means shall be provided so that any of the conditions and malfunctioning enumerated in 3.5.4.7.2.2, 3.5.4.7.2.3 and 3.5.4.7.2.4 which are monitored can persist for a certain period before the monitor takes action. 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.

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

3.5.4.7.3 *DME/P monitoring action*

3.5.4.7.3.1 The monitor system shall cause the transponder radiation to cease and provide a warning at a control point if any of the following conditions persist for longer than the period specified:

a) there is a change in transponder PFE that exceeds the limits specified in either 3.5.4.5.3 or 3.5.4.5.4 for more than one second. If the FA mode limit is exceeded, but the IA mode limit is maintained, the IA mode may remain operative;

b) there is a reduction in the EIRP to less than that necessary to satisfy the requirements specified in 3.5.4.1.5.3 for a period of more than one second;

c) there is a reduction of 3 dB or more in the transponder sensitivity necessary to satisfy the requirements specified in 3.5.4.2.3 for a period of more than five seconds in FA mode and ten seconds in IA mode (provided that this is not due to the action of the receiver automatic sensitivity reduction circuits);

d) the spacing between the first and second pulse of the transponder reply pulse pair differs from the value specified in the table in 3.5.4.4.1 by 0.25 microsecond or more for a period of more than one second.

3.5.4.7.3.2 **Recommendation.—** *The monitor should cause a suitable indication to be given at a control point if there is an increase above 0.3 microseconds or a decrease below 0.2 microseconds of the reply pulse partial rise time which persists for more than one second.*

3.5.4.7.3.3 The period during which erroneous guidance information is radiated shall not exceed the periods specified in 3.5.4.7.3.1. Attempts to clear a fault by resetting the primary ground equipment or by switching to standby ground equipment, if fitted, shall be completed within this time. If the fault is not cleared within the time allowed, the radiation shall cease. After shutdown, no attempt shall be made to restore service until a period of 20 seconds has elapsed.

3.5.4.7.3.4 The transponder shall not be triggered for monitoring purposes more than 120 times per second in the IA mode and 150 times per second in the FA mode.

3.5.4.7.3.5 *DME/N and DME/P monitor failure.* Failure of any part of the monitor itself shall automatically produce the same results as the malfunctioning of the element being monitored.

3.5.5 Technical characteristics of interrogator

Note.— The following subparagraphs specify only those interrogator parameters which must be defined to ensure that the interrogator:

a) does not jeopardize the effective operation of the DME system, e.g. by increasing transponder loading abnormally; and

b) is capable of giving accurate distance readings.

3.5.5.1 *Transmitter*

3.5.5.1.1 *Frequency of operation.* The interrogator shall transmit on the interrogation frequency appropriate to the assigned DME channel (see 3.5.3.3.3).

Note.— This specification does not preclude the use of airborne interrogators having less than the total number of operating channels.

3.5.5.1.2 *Frequency stability.* The radio frequency of operation shall not vary more than plus or minus 100 kHz from the assigned value.

3.5.5.1.3 *Pulse shape and spectrum.* The following shall apply to all radiated pulses:

a) *Pulse rise time.*

1) *DME/N.* Pulse rise time shall not exceed 3 microseconds.

2) *DME/P*. Pulse rise time shall not exceed 1.6 microseconds. For the FA mode, the pulse shall have a partial rise time of 0.25 plus or minus 0.05 microsecond. With respect to the FA mode and accuracy standard 1, the slope of the pulse in the partial rise time shall not vary by more than plus or minus 20 per cent. For accuracy standard 2 the slope shall not vary by more than plus or minus 10 per cent.

3) *DME/P*. **Recommendation.—** *Pulse rise time should not exceed 1.2 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.

f) 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. Initiation of the turn-on process shall not commence sooner than 1 microsecond prior to the virtual origin.

Note 1.— The lower limit of pulse rise time (see 3.5.5.1.3 a)) and decay time (see 3.5.5.1.3 c)) are governed by the spectrum requirements in 3.5.5.1.3 e).

Note 2.— While 3.5.5.1.3 e) calls for a practically attainable spectrum, it is desirable to strive for the following spectrum control characteristics: the spectrum of the pulse modulated signal is such that the power contained in a 0.5 MHz band centred on frequencies 0.8 MHz above and 0.8 MHz below the nominal channel frequency is, in each case, at least 23 dB below the power contained in a 0.5 MHz band centred on the nominal channel frequency. The power contained in a 0.5 MHz band centred on frequencies 2 MHz above and 2 MHz below the nominal channel frequency is, in each case, at least 38 dB below the power contained in a 0.5 MHz band centred on the nominal channel frequency. Any additional lobe of the spectrum is of less amplitude than the adjacent lobe nearer the nominal channel frequency.

3.5.5.1.4 *Pulse spacing*

3.5.5.1.4.1 The spacing of the constituent pulses of transmitted pulse pairs shall be as given in the table in 3.5.4.4.1.

3.5.5.1.4.2 *DME/N.* The tolerance on the pulse spacing shall be plus or minus 0.5 microsecond.

3.5.5.1.4.3 *DME/N.* **Recommendation.—** *The tolerance on the pulse spacing should be plus or minus 0.25 microsecond.*

3.5.5.1.4.4 *DME/P.* The tolerance on the pulse spacing shall be plus or minus 0.25 microsecond.

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

3.5.5.1.5 *Pulse repetition frequency*

3.5.5.1.5.1 The pulse repetition frequency shall be as specified in 3.5.3.4.

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

3.5.5.1.5.3 *DME/P.* In order to achieve the system accuracy specified in 3.5.3.1.4, the variation in time between successive pairs of interrogation pulses shall be sufficiently random to decorrelate high frequency multipath errors.

Note.— Guidance on DME/P multipath effects is given in Attachment C, 7.3.7.

3.5.5.1.6 *Spurious radiation.* 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 be more than 50 dB below the peak pulse power received and measured in the same receiver tuned to the interrogation frequency in use during the transmission of the required pulses. This provision 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).

Note.— Although spurious CW radiation between pulses is limited to levels not exceeding minus 47 dBW, States are cautioned that where DME interrogators and secondary surveillance radar transponders are employed in the same aircraft, it may be necessary to provide protection to airborne SSR in the band 1 015 MHz to 1 045 MHz. This protection may be provided by limiting conducted and radiated CW to a level of the order of minus 77 dBW. Where this level cannot be achieved, the required degree of protection may be provided in planning the relative location of the SSR and DME aircraft antennas. It is to be noted that only a few of these frequencies are utilized in the VHF/DME pairing plan.

3.5.5.1.7 **Recommendation.—** *The spurious pulse power received and measured under the conditions stated in 3.5.5.1.6 should be 80 dB below the required peak pulse power received.*

Note.— Reference 3.5.5.1.6 and 3.5.5.1.7 — although limitation of spurious CW radiation between pulses to levels not exceeding 80 dB below the peak pulse power received is recommended, States are cautioned that where users employ airborne secondary surveillance radar transponders in the same aircraft, it may be necessary to limit direct and radiated CW to not more than 0.02 microwatt in the frequency band 1 015 MHz to 1 045 MHz. It is to be noted that only a few of these frequencies are utilized in the VHF/DME pairing plan.

3.5.5.1.8 *DME/P.* The peak EIRP shall not be less than that required to ensure the power densities in 3.5.4.2.3.1 under all operational weather conditions.

3.5.5.2 *Time delay*

3.5.5.2.1 The time delay shall be consistent with the table in 3.5.4.4.1.

3.5.5.2.2 *DME/N.* 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.

‡3.5.5.2.3 *DME/N.* 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.

3.5.5.2.4 *DME/P — IA mode.* 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.

3.5.5.2.5 *DME/P — FA mode.* The time delay shall be the interval between the virtual origin of 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. The time of arrival shall be measured within the partial rise time of the pulse.

3.5.5.3 *Receiver*

3.5.5.3.1 *Frequency of operation.* The receiver centre frequency shall be the transponder frequency appropriate to the assigned DME operating channel (see 3.5.3.3.3).

3.5.5.3.2 *Receiver sensitivity*

‡3.5.5.3.2.1 *DME/N.* The airborne equipment sensitivity shall be sufficient to acquire and provide distance information to the accuracy specified in 3.5.5.4 for the signal power density specified in 3.5.4.1.5.2.

Note.— Although the Standard in 3.5.5.3.2.1 is for DME/N interrogators, the receiver sensitivity is better than that necessary in order to operate with the power density of DME/N transponders given in 3.5.4.1.5.1 in order to assure interoperability with the IA mode of DME/P transponders.

3.5.5.3.2.2 *DME/P.* The airborne equipment sensitivity shall be sufficient to acquire and provide distance information to the accuracy specified in 3.5.5.4.2 and 3.5.5.4.3 for the signal power densities specified in 3.5.4.1.5.3.

‡3.5.5.3.2.3 *DME/N.* 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 3.5.4.1.5 and a maximum of minus 18 dBW/m^2.

3.5.5.3.2.4 *DME/P*. 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 3.5.4.1.5 and a maximum of minus 18 dBW/m^2.

3.5.5.3.3 *Bandwidth*

3.5.5.3.3.1 *DME/N*. The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3, when the input signals are those specified in 3.5.4.1.3.

3.5.5.3.3.2 *DME/P — IA mode.* The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.4.1.3. The 12-dB bandwidth shall not exceed 2 MHz and the 60-dB bandwidth shall not exceed 10 MHz.

3.5.5.3.3.3 *DME/P — FA mode.* The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3. The 12-dB bandwidth shall not exceed 6 MHz and the 60-dB bandwidth shall not exceed 20 MHz.

3.5.5.3.4 *Interference rejection*

3.5.5.3.4.1 When 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.

Note.— Co-channel refers to those reply signals that utilize the same frequency and the same pulse pair spacing.

‡3.5.5.3.4.2 *DME/N*. 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 be rejected.

3.5.5.3.4.3 *DME/P*. 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 be rejected.

3.5.5.3.5 *Decoding*

3.5.5.3.5.1 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 3.5.4.1.4.

‡3.5.5.3.5.2 *DME/N — Decoder rejection.* A reply pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to 42 dB above the receiver sensitivity shall be rejected.

3.5.5.3.5.3 *DME/P — Decoder rejection.* A reply pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to 42 dB above the receiver sensitivity shall be rejected.

3.5.5.4 *Accuracy*

‡3.5.5.4.1 *DME/N*. 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.

3.5.5.4.2 *DME/P — IA mode.* The interrogator shall not contribute more than plus or minus 30 m (plus or minus 100 ft) to the overall system PFE and not more than plus or minus 15 m (plus or minus 50 ft) to the overall system CMN.

Note.— Unless specifically indicated as the MLS airborne equipment, the text in 3.11 refers to the MLS ground equipment.

3.11.3 MLS configurations

3.11.3.1 *Basic MLS.* The basic configuration of the MLS shall be composed of the following:

a) approach azimuth equipment, associated monitor, remote control and indicator equipment;

b) approach elevation equipment, associated monitor, remote control and indicator equipment;

c) a means for the encoding and transmission of essential data words, associated monitor, remote control and indicator equipment;

Note.— The essential data are those basic and essential auxiliary data words specified in 3.11.5.4.

d) DME/N, associated monitor, remote control and indicator equipment.

3.11.3.2 **Recommendation.—** *If precise ranging information throughout the azimuth coverage sector is required, the option of DME/P, conforming to the Standards of Chapter 3, 3.5 should be applied.*

Note.— DME is the MLS ranging element and is expected to be installed as soon as possible. However, marker beacons installed for ILS may be used temporarily with MLS while ILS service is maintained at the same runway.

3.11.3.3 *Expanded MLS configurations.* It shall be permissible to derive expanded configurations from the basic MLS, by addition of one or more of the following functions or characteristic improvements:

a) back azimuth equipment, associated monitor, remote control and indicator equipment;

b) flare elevation equipment, associated monitor, remote control and indicator equipment;

c) DME/P, associated monitor, remote control and indicator equipment;

d) a means for the encoding and transmission of additional auxiliary data words, associated monitor, remote control and indicator equipment;

e) a wider proportional guidance sector exceeding the minimum specified in 3.11.5.

Note 1.— Although the Standard has been developed to provide for flare elevation function, this function is not implemented and is not intended for future implementation.

Note 2.— The MLS signal format allows further system growth to include additional functions, such as 360 degrees azimuth.

3.11.3.4 *Simplified MLS configurations*. It shall be permissible to derive simplified configurations from the basic MLS (3.11.3.1), by relaxation of characteristics as follows:

a) an approach azimuth coverage provided in approach region (3.11.5.2.2.1.1) only;

b) an approach azimuth and elevation coverage (3.11.5.2.2 and 3.11.5.3.2) not extending below a height of 30 m (100 ft) above the threshold;

c) accuracy limits for PFE and PFN expanded to be not greater than 1.5 times the values specified in 3.11.4.9.4 for approach azimuth guidance and in 3.11.4.9.6 for elevation guidance;

d) ground equipment contribution to the mean course error and to the mean glide path error expanded to be 1.5 times the values specified in 3.11.5.2.5 and 3.11.5.3.5, respectively;

e) CMN requirements (3.11.4.9.4 and 3.11.4.9.6) waived; and

f) monitor and control action period (3.11.5.2.3 and 3.11.5.3.3) expanded to a six-second period.

Note.— Guidance material on application of the simplified MLS configurations is provided in Attachment G, 15.

3.11.4 Signal-in-space characteristics — angle and data functions

3.11.4.1 *Channelling*

3.11.4.1.1 *Channel arrangement.* The MLS angle and data functions shall operate on any one of the 200 channels assigned on the frequencies from 5 031.0 MHz to 5 090.7 MHz as shown in Table A.

3.11.4.1.1.1 Channel assignments in addition to those specified in 3.11.4.1.1 shall be made within the 5 030.4 to 5 150.0 MHz sub-band as necessary to satisfy future air navigation requirements.

3.11.4.1.2 *Channel pairing with DME.* The channel pairing of the angle and data channel with the channel of the ranging function shall be in accordance with Table A.

3.11.4.1.3 *Frequency tolerance.* The operating radio frequency of the ground equipment shall not vary more than plus or minus 10 kHz from the assigned frequency. The frequency stability shall be such that there is no more than a plus or minus 50 Hz deviation from the nominal frequency when measured over a one-second interval.

3.11.4.1.4 *Radio frequency signal spectrum*

3.11.4.1.4.1 The transmitted signal shall be such that, during the transmission time, the mean power density above a height of 600 m (2 000 ft) shall not exceed –94.5 dBW/m^2 for angle guidance or data signals, as measured in a 150 kHz bandwidth centred 840 kHz or more from the nominal frequency.

3.11.4.1.4.2 The transmitted signal shall be such that, during the transmission time, the mean power density beyond a distance of 4 800 m (2.6 NM) from any antennas and for a height below 600 m (2 000 ft) shall not exceed –94.5 dBW/m^2 for angle guidance or data signals, as measured in a 150 kHz bandwidth centred 840 kHz or more from the nominal frequency.

Note 1.— Requirements in 3.11.4.1.4.2 are applicable when the operational coverage of another MLS ground station has overlap with the radio-horizon of the considered ground station.

Note 2.— Guidance material on MLS frequency planning is provided in Attachment G, 9.3.

3.11.4.2 *Polarization.* The radio frequency transmissions from all ground equipment shall be nominally vertically polarized. The effect of any horizontally polarized component shall not cause the guidance information to change by more than 40 per cent of the PFE allowed at that location with the airborne antenna rotated 30 degrees from the vertical position or cause the PFE limit to be exceeded.

3.11.4.9 *System accuracy.* The accuracy standards specified herein shall be met on a 95 per cent probability basis unless otherwise stated.

Note 1.— The overall error limits include errors from all causes such as those from airborne equipment, ground equipment, and propagation effects.

Note 2.— It is intended that the error limits are to be applied over a flight path interval that includes the approach reference datum or back azimuth reference datum. Information on the interpretation of MLS errors and the measurement of these errors over an interval appropriate for flight inspection is provided in Attachment G, 2.5.2.

Note 3.— To determine the allowable errors for degradation allowances at points other than the appropriate reference datum, the accuracy specified at the reference datum should first be converted from its linear value into its equivalent angular value with an origin at the antenna.

3.11.4.9.1 *MLS approach reference datum.* The height of the MLS approach reference datum shall be 15 m (50 ft). A tolerance of plus 3 m (10 ft) shall be permitted.

Note 1.— The operational objective of defining the height of the MLS approach reference datum is to ensure safe guidance over obstructions and also safe and efficient use of the runway served. The heights noted in 3.11.4.9.1 assume Code 3 or Code 4 runways as defined by Annex 14.

Note 2.— At the same time, the reference datum is to provide a convenient point at which the accuracy and other parameters of the function may be specified.

Note 3.— In arriving at the above height values for the MLS approach reference datum, a maximum vertical distance of 5.8 m (19 ft) between the path of the aircraft MLS antenna selected for final approach and the path of the lowest part of the wheels at the threshold was assumed. For aircraft exceeding this criterion, appropriate steps may have to be taken either to maintain adequate clearance at threshold or to adjust the permitted operating minima.

3.11.4.9.2 *MLS back azimuth reference datum.* The height of the MLS back azimuth reference datum shall be 15 m (50 ft). A tolerance of plus 3 m (10 ft) shall be permitted.

Note.— The objective of defining the MLS back azimuth reference datum is to provide a convenient point at which the accuracy and other parameters of the function may be specified.

3.11.4.9.3 The PFE shall be comprised of those frequency components of the guidance signal error at the output of the airborne receiver which lie below 0.5 rad/s for azimuth guidance information or below 1.5 rad/s for elevation guidance information. The control motion noise shall be comprised of those frequency components of the guidance signal error at the output of the airborne receiver which lie above 0.3 rad/s for azimuth guidance or above 0.5 rad/s for elevation guidance information. The output filter corner frequency of the receiver used for this measurement is 10 rad/s.

3.11.4.9.4 *Approach azimuth guidance functions.* Except as allowed for simplified MLS configurations in 3.11.3.4, at the approach reference datum, the approach azimuth function shall provide performance as follows:

a) the PFE shall not be greater than plus or minus 6 m (20 ft);

b) the PFN shall not be greater than plus or minus 3.5 m (11.5 ft);

c) the CMN shall not be greater than plus or minus 3.2 m (10.5 ft) or 0.1 degree, whichever is less.

3.11.4.9.4.1 **Recommendation.—** *At the approach reference datum, the PFE should not be greater than plus or minus 4 m (13.5 ft).*

3.11.4.9.4.2 The linear accuracy specified at the reference datum shall be maintained throughout the runway coverage region specified in 3.11.5.2.2.1.2 except where degradation is allowed as specified in 3.11.4.9.4.3.

3.11.4.9.4.3 *Degradation allowance.* Except as allowed for simplified MLS configurations in 3.11.3.4, the approach azimuth angular PFE, PFN and CMN shall be allowed to degrade linearly to the limits of coverage as follows:

a) *With distance.* The PFE limit and PFN limit, expressed in angular terms at 37 km (20 NM) from the runway threshold along the extended runway centre line, shall be 2 times the value specified at the approach reference datum. The CMN limit shall be 0.1 degree at 37 km (20 NM) from the approach reference datum along the extended runway centre line at the minimum glide path angle.

b) *With azimuth angle.* The PFE limit and PFN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, shall be 1.5 times the value on the extended runway centre line at the same distance from the approach reference datum. The CMN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle is 1.3 times the value on the extended runway centre line at the same distance from the approach reference datum.

c) *With elevation angle.* The PFE limit and PFN limit shall not degrade up to an elevation angle of 9 degrees. The PFE limit and PFN limit, expressed in angular terms at an elevation angle of 15 degrees from the approach azimuth antenna phase centre, shall be 2 times the value permitted below 9 degrees at the same distance from the approach reference datum and the same azimuth angle. The CMN limit shall not degrade with elevation angle.

d) *Maximum CMN.* The CMN limits shall not exceed 0.2 degree in any region of coverage.

3.11.4.9.4.3.1 **Recommendation.—** *The CMN should not exceed 0.1 degree in any region of coverage.*

3.11.4.9.4.4 *Maximum angular PFE and PFN.* Except as allowed for simplified MLS configurations in 3.11.3.4, in any region within coverage, the angular error limits shall be as follows:

a) the PFE shall not exceed plus or minus 0.25 degree; and

b) the PFN shall not exceed plus or minus 0.15 degree.

3.11.4.9.5 *Back azimuth guidance function.* At the back azimuth reference datum, the back azimuth function shall provide performance as follows:

a) the PFE shall not be greater than plus or minus 6 m (20 ft);

b) the PFN component shall not be greater than plus or minus 3.5 m (11.5 ft);

c) the CMN shall not be greater than plus or minus 3.2 m (10.5 ft) or 0.1 degree, whichever is less.

3.11.4.9.5.1 *Degradation allowance.* The back azimuth angular PFE, PFN and CMN shall be allowed to degrade linearly to the limits of coverage as follows:

a) *With distance.* The PFE limit and PFN limit, expressed in angular terms at the limit of coverage along the extended runway centre line, shall be 2 times the value specified at the back azimuth reference datum. The CMN limit, expressed in angular terms at 18.5 km (10 NM) from the runway stop end along the extended runway centre line, shall be 1.3 times the value specified at the back azimuth reference datum.

b) *With azimuth angle.* The PFE limit and PFN limit, expressed in angular terms at plus or minus 20 degrees azimuth angle, shall be 1.5 times the value on the extended runway centre line at the same distance from the back azimuth reference datum. The CMN limit, expressed in angular terms at plus or minus 20 degrees azimuth angle, shall be 1.3 times the value on the extended runway centre line at the same distance from the back azimuth reference datum.

c) *With elevation angle.* The PFE limit and PFN limit shall not degrade up to an elevation angle of 9 degrees. The PFE limit and PFN limit, expressed in angular terms at an elevation angle of 15 degrees from the back azimuth antenna phase centre, shall be 2 times the value permitted below 9 degrees at the same distance from the back azimuth reference datum and the same azimuth angle. The CMN limit shall not degrade with elevation angle.

d) *Maximum CMN.* The CMN limits shall not exceed 0.2 degree in any region of coverage.

3.11.4.9.5.2 *Maximum angular PFE and PFN.* In any region within coverage, the angular error limits shall be as follows:

a) the PFE shall not exceed plus or minus 0.50 degree; and

b) the PFN shall not exceed plus or minus 0.30 degree.

3.11.4.9.6 *Elevation guidance function.* For equipment sited to provide a minimum glide path of nominally 3 degrees or lower, except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation function shall provide performance at the approach reference datum as follows:

a) the PFE shall not be greater than plus or minus 0.6 m (2 ft);

b) the PFN shall not be greater than plus or minus 0.4 m (1.3 ft);

c) the CMN shall not be greater than plus or minus 0.3 m (1 ft).

3.11.4.9.6.1 *Degradation allowance.* Except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation angular PFE, PFN and CMN shall be allowed to degrade linearly to the limits of coverage as follows:

a) *With distance.* The PFE limit and PFN limit, expressed in angular terms at 37 km (20 NM) from the runway threshold on the minimum glide path, shall be 0.2 degree. The CMN limit shall be 0.1 degree at 37 km (20 NM) from the approach reference datum along the extended runway centre line at the minimum glide path angle.

b) *With azimuth angle.* The PFE limit and PFN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, shall be 1.3 times the value on the extended runway centre line at the same distance from the approach reference datum. The CMN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, shall be 1.3 times the value on the extended runway centre line at the same distance from the approach reference datum.

c) *With elevation angle.* For elevation angles above the minimum glide path or 3 degrees, whichever is less and up to the maximum of the proportional guidance coverage and at the locus of points directly above the approach reference datum the PFE limit, PFN limit and the CMN limit expressed in angular terms shall be allowed to degrade linearly such that at an elevation angle of 15 degrees the limits are 2 times the value specified at the reference datum. In no case shall the CMN directly above the reference datum exceed plus or minus 0.07 degree. For other regions of coverage within the angular sector from an elevation angle equivalent to the minimum glide path up to the maximum angle of proportional coverage, the degradations with distance and azimuth angle specified in a) and b) shall apply.

d) The PFE, PFN and CMN limits shall not degrade with elevation angle in the region between the minimum glide path and 60 per cent of the minimum glide path. For elevation angles below 60 per cent of the minimum glide path and down to the limit of coverage specified in 3.11.5.3.2.1.2, and at the locus of points directly below the approach reference datum the PFE limit, the PFN limit and the CMN limit expressed in angular terms, shall be allowed to increase linearly to 6 times the value at the approach reference datum. For other regions of coverage within the angular sector from an elevation angle equivalent to 60 per cent of the minimum glide path angle value, and down to the limit of coverage, the degradation with distance and azimuth angle specified in a) and b) shall apply. In no case shall the PFE be allowed to exceed 0.8 degree, or the CMN be allowed to exceed 0.4 degree.

e) *Maximum CMN.* For elevation angles above 60 per cent of the minimum glide path, the CMN limits shall not exceed 0.2 degree in any region of coverage.

3.11.4.9.6.2 *Maximum angular PFE and PFN.* Except as allowed for simplified MLS configurations in 3.11.3.4, in any region within coverage, the angular error limits for elevation angles above 60 per cent of the minimum glide path shall be as follows:

a) the PFE shall not exceed plus or minus 0.25 degree; and

b) the PFN shall not exceed plus or minus 0.15 degree.

3.11.4.9.6.3 **Recommendation.—** *The limit expressed in angular terms on the linear degradation of the PFE limit, the PFN limit and the CMN limit at angles below 60 per cent of the minimum glide path and down to the limit of coverage should be 3 times the value permitted at the approach reference datum.*

Note.— For other regions of coverage within the angular sector from an elevation angle equivalent to 60 per cent of the minimum glide path and down to the limit of coverage, the degradation with distance and azimuth angle specified in 3.11.4.9.6.1 a) and b) applies.

3.11.4.9.6.4 **Recommendation.—** Maximum CMN. *For elevation angles above 60 per cent of the minimum glide path, the CMN limits should not exceed 0.1 degree in any region of coverage.*

3.11.4.9.6.5 **Recommendation.—** *The PFE should not exceed 0.35 degree, and the CMN should not exceed 0.2 degree.*

3.11.4.9.6.6 Approach elevation equipment sited to provide a minimum glide path higher than 3 degrees shall provide angular accuracies not less than those specified for equipment sited for a 3-degree minimum glide path within the coverage volume.

3.11.4.10 *Power density*

3.11.4.10.1 The power density for DPSK, clearance and angle guidance signals shall be at least the values shown in the following table under all operational weather conditions at any point within coverage except as specified in 3.11.4.10.2.

Function	*DPSK signals (dBW/m^2)*	*Angle signals (dBW/m^2) 1°*	*2°*	*3°*	*Clearance signals (dBW/m^2)*
		(antenna beamwidth)			
Approach azimuth guidance	–89.5	–85.7	–79.7	–76.2	–88.0
High rate approach azimuth guidance	–89.5	–88.0	–84.5	–81.0	–88.0
Back azimuth guidance	–89.5	–88.0	–82.7	–79.2	–88.0
Approach elevation guidance	–89.5	–88.0	–84.5	N/A	N/A

N/A = not applicable

Note.— The table above specifies the minimum power densities for clearance signals and scanning beam signals. The relative values of the two signals are specified in 3.11.4.6.2.5.2.

3.11.4.10.2 The power density of the approach azimuth angle guidance signals shall be greater than that specified in 3.11.4.10.1 by at least:

a) 15 dB at the approach reference datum;

b) 5 dB for one degree or 9 dB for 2 degree or larger beamwidth antennas at 2.5 m (8 ft) above the runway surface, at the MLS datum point, or at the farthest point of the runway centre line which is in line of sight of the azimuth antenna.

Note 1.— Near the runway surface the approach azimuth equipment will normally provide power densities higher than those specified for angle signals in 3.11.4.10.1 to support auto-land operations. Attachment G provides guidance as regards antenna beamwidth and power budget considerations.

Note 2.— The specifications for coverage in 3.11.5.2.2 and 3.11.5.3.2 make provision for difficult ground equipment siting conditions in which it may not be feasible to provide the power density specified in 3.11.4.10.2.

3.11.4.10.3 *Multipath relative power densities*

3.11.4.10.3.1 Within the MLS azimuth coverage at 60 m (200 ft) or more above threshold, the duration of a reflected scanning beam signal whose power density is higher than four decibels below the approach azimuth guidance, or high rate azimuth guidance scanning beam signal power density, shall be shorter than one second, as seen by an aircraft on a published approach.

3.11.4.10.3.2 Within the MLS azimuth proportional guidance sector, below 60 m (200 ft) above threshold, the power density of any reflected approach azimuth guidance or high rate approach azimuth guidance scanning beam signal shall be less than ten decibels above the power density of the approach azimuth guidance or high rate approach azimuth guidance scanning beam signal. On the runway centre line, this reflected signal shall not degrade the azimuth scanning beam shape and generate at the output of a receiver an error beyond the tolerances as stated in 3.11.4.9.

3.11.4.10.3.3 Within the MLS elevation coverage, the duration of a reflected approach elevation guidance scanning beam signal whose power density is higher than four decibels below the approach elevation guidance scanning beam signal power density shall be shorter than one second, as seen by an aircraft on a published approach.

3.11.5 Ground equipment characteristics

3.11.5.1 *Synchronization and monitoring.* The synchronization of the time-division-multiplexed angle guidance and data transmissions which are listed in 3.11.4.3.3 shall be monitored.

Note.— Specific monitoring requirements for various MLS functions are specified in 3.11.5.2.3 and 3.11.5.3.3.

3.11.5.1.1 *Residual radiation of MLS functions.* The residual radiation of an MLS function at times when another function is radiating shall be at least 70 dB below the level provided when transmitting.

Note.— The acceptable level of residual radiation for a particular function is that level which has no adverse effect on the reception of any other function and is dependent upon equipment siting and aircraft position.

3.11.5.2 *Azimuth guidance equipment*

3.11.5.2.1 *Scanning beam characteristics.* Azimuth ground equipment antennas shall produce a fan-shaped beam which is narrow in the horizontal plane, broad in the vertical plane and which is scanned horizontally between the limits of the proportional guidance sector.

3.11.5.2.1.1 *Coordinate system.* Azimuth guidance information shall be radiated in either conical or planar coordinates.

3.11.5.2.1.2 *Antenna beamwidth.* The antenna beamwidth shall not exceed 4 degrees.

Note.— It is intended that the detected scanning beam envelope, throughout the coverage should not exceed 250 microseconds (equivalent to a beamwidth of 5 degrees) in order to ensure proper angle decoding by the airborne equipment.

3.11.5.2.1.3 *Scanning beam shape.* The minus 10-dB points on the beam envelope shall be displaced from the beam centre by at least 0.76 beamwidth, but not more than 0.96 beamwidth.

Note.— The beam shape described applies on boresight in a multipath free environment using a suitable filter. Information on beam shape and side lobes is provided in Attachment G, 3.1 and 3.2.

3.11.5.2.2 *Coverage*

Note.— Diagrams illustrating the coverage requirements specified herein are contained in Attachment G, Figures G-5A, G5-B and G-6.

3.11.5.2.2.1 *Approach azimuth.* Except as allowed for simplified MLS configurations in 3.11.3.4, the approach azimuth ground equipment shall provide guidance information in at least the following volumes of space:

3.11.5.2.2.1.1 *Approach region.*

a) Laterally, within a sector of 80 degrees (normally plus and minus 40 degrees about the antenna boresight) which originates at the approach azimuth antenna phase centre.

b) Longitudinally, from the approach azimuth antenna to 41.7 km (22.5 NM).

c) Vertically, between:

   1) a lower conical surface originating at the approach azimuth antenna phase centre and inclined upward to reach, at the longitudinal coverage limit, a height of 600 m (2 000 ft) above the horizontal plane which contains the antenna phase centre; and

   2) an upper conical surface originating at the approach azimuth antenna phase centre inclined at 15 degrees above the horizontal to a height of 6 000 m (20 000 ft).

Note 1.— Where intervening obstacles penetrate the lower surface, it is intended that guidance need not be provided at less than line-of-sight heights.

Note 2.— Where it is determined that misleading guidance information exists outside the promulgated coverage sector and appropriate operational procedures cannot provide an acceptable solution, techniques to minimize the effects are available. These techniques include adjustment of the proportional guidance sector or use of out-of-coverage indication signals. Guidance material on the use of these techniques is contained in Attachment G, 8.

Note 3.— Where the proportional guidance sector provided is less than the minimum lateral coverage specified in 3.11.5.2.2.1.1 a), clearance guidance signals specified in 3.11.4.6.2.5 are required.

3.11.5.2.2.1.2 *Runway region.*

a) Horizontally within a sector 45 m (150 ft) each side of the runway centre line beginning at the stop end and extending parallel with the runway centre line in the direction of the approach to join the minimum operational coverage region as described in 3.11.5.2.2.1.3.

b) Vertically between:

1) a horizontal surface which is 2.5 m (8 ft) above the farthest point of the runway centre line which is in line of sight of the azimuth antenna; and

2) a conical surface originating at the azimuth ground equipment antenna inclined at 20 degrees above the horizontal up to a height of 600 m (2 000 ft).

Note 1.— Information on the determination of the point referred to in b) 1) is given in Attachment G, 2.3.6.

Note 2.— It is intended that guidance below the line of sight may be allowed as long as the signal quality can satisfy the accuracy requirements in 3.11.4.9.4.

3.11.5.2.2.1.2.1 **Recommendation.—** *The lower level of the coverage in the runway region should be 2.5 m (8 ft) above the runway centre line.*

3.11.5.2.2.1.2.2 Where required to support automatic landing, roll-out or take-off, the lower level of coverage in the runway region shall not exceed 2.5 m (8 ft) above the runway centre line.

Note.— The lower coverage limit of 2.5 m (8 ft) is intended to serve all runways. Information on the possibility of relaxing the power density requirements in 3.11.4.10.2 at 2.5 m (8 ft) is provided at Attachment G, 2.3.6.

3.11.5.2.2.1.3 *Minimum operational coverage region.*

a) Laterally, within a sector of plus and minus 10 degrees about the runway centre line which originates at the MLS datum point.

b) Longitudinally, from the runway threshold in the direction of the approach to the longitudinal coverage limit specified in 3.11.5.2.2.1.1 b).

c) Vertically, between:

1) a lower plane which contains the line 2.5 m (8 ft) above the runway threshold and is inclined upward to reach the height of the surface specified in 3.11.5.2.2.1.1 c) 1) at the longitudinal coverage limit; and

2) the upper surface specified in 3.11.5.2.2.1.1 c) 2).

3.11.5.2.2.1.4 **Recommendation.—** *The approach azimuth ground equipment should provide guidance vertically to 30 degrees above the horizontal.*

3.11.5.2.2.1.5 The minimum proportional guidance sector shall be as follows:

Approach azimuth antenna to threshold distance (AAT)	Minimum proportional coverage
AAT < 500 m (1 640 ft)	±8°
500 m (1 640 ft) < AAT < 3 100 m (10 170 ft)	±6°
3 100 m (10 170 ft) < AAT	±4°

3.11.5.2.2.2 *Back azimuth.* The back azimuth ground equipment shall provide information in at least the following volume of space:

a) Horizontally, within a sector plus or minus 20 degrees about the runway centre line originating at the back azimuth ground equipment antenna and extending in the direction of the missed approach at least 18.5 km (10 NM) from the runway stop end.

b) Vertically, in the runway region between:

   1) a horizontal surface 2.5 m (8 ft) above the farthest point of runway centre line that is in line-of-sight of the back azimuth antenna; and

   2) a conical surface originating at the back azimuth ground equipment antenna inclined at 20 degrees above the horizontal up to a height of 600 m (2 000 ft).

c) Vertically, in the back azimuth region between:

   1) a conical surface originating 2.5 m (8 ft) above the runway stop end, inclined at 0.9 degree above the horizontal; and

   2) a conical surface originating at the back azimuth ground equipment antenna, inclined at 15 degrees above the horizontal up to a height of 3 000 m (10 000 ft).

Note 1.— Information on the determination of the point referred to in b) 1) is given in Attachment G, 2.3.6.

Note 2.— When physical characteristics of the runway or obstacles prevent the achievement of the Standards in b) and c), it is intended that guidance need not be provided at less than line-of-sight heights.

3.11.5.2.2.2.1 **Recommendation.—** *The back azimuth facility should provide guidance information to 30 degrees above the horizontal.*

3.11.5.2.2.2.2 The minimum proportional guidance sector shall be plus or minus 10 degrees about the runway centre line.

Note.— Application information is provided in Attachment G, 7.5.

3.11.5.2.3 *Monitor and control*

3.11.5.2.3.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the approach azimuth and back azimuth monitor systems shall cause the radiation of their respective functions to cease and a warning shall be provided at the designated control points if any of the following conditions persist for longer than the periods specified:

a) there is a change in the ground equipment contribution to the mean course error such that the PFE at the approach reference datum or in the direction of any azimuth radial exceeds the limits specified in 3.11.4.9.4 and 3.11.4.9.5 for a period of more than one second;

b) there is a reduction in the radiated power to less than that necessary to satisfy the requirements specified in 3.11.4.10.1 and 3.11.4.6.2.5.2 for a period of more than one second;

c) there is an error in the preamble DPSK transmissions which occurs more than once in any one-second period;

d) there is an error in the TDM synchronization of a particular azimuth function such that the requirement specified in 3.11.4.3.2 is not satisfied, and this condition persists for more than one second.

Note.— Guidance material is provided in Attachment G, 6.

3.11.5.2.3.2 Design and operation of the monitor system shall cause radiation to cease and a warning shall be provided at the designated control points in the event of failure of the monitor system itself.

3.11.5.2.3.3 The period during which erroneous guidance information is radiated, including period(s) of zero radiation, shall not exceed the periods specified in 3.11.5.2.3.1. Any attempts to clear a fault by resetting the primary ground equipment or by switching to standby ground equipment shall be completed within this time, and any period(s) of zero radiation shall not exceed 500 milliseconds. If the fault is not cleared within the time allowed, the radiation shall cease. After shutdown, no attempt shall be made to restore service until a period of 20 seconds has elapsed.

3.11.5.2.4 *Integrity and continuity of service requirements for MLS azimuth*

3.11.5.2.4.1 The probability of not radiating false guidance signals shall not be less than $1 - 0.5 \times 10^{-9}$ in any one landing for an MLS azimuth intended to be used for Categories II and III operations.

3.11.5.2.4.2 **Recommendation.—** *The probability of not radiating false guidance signals should not be less than $1 - 1.0 \times 10^{-7}$ in any one landing for an MLS azimuth intended to be used for Category I operations.*

3.11.5.2.4.3 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 an MLS azimuth intended to be used for Category II or Category IIIA operations (equivalent to 2 000 hours mean time between outages); and

b) $1 - 2 \times 10^{-6}$ in any period of 30 seconds for an MLS azimuth intended to be used for the full range of Category III operations (equivalent to 4 000 hours mean time between outages).

3.11.5.2.4.4 **Recommendation.—** *The probability of not losing the radiated guidance signal should exceed $1 - 4 \times 10^{-6}$ in any period of 15 seconds for an MLS azimuth intended to be used for Category I operations (equivalent to 1 000 hours mean time between outages).*

Note.— Guidance material on integrity and continuity of service is given in Attachment G, 11.

3.11.5.2.5 *Ground equipment accuracy*

3.11.5.2.5.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the ground equipment contribution to the mean course error shall not exceed an error equivalent to plus or minus 3 m (10 ft) at the MLS approach reference datum.

3.11.5.2.5.2 **Recommendation.—** *The ground equipment contribution to the CMN at the reference datum should not exceed 1 m (3.3 ft) or 0.03 degree, whichever is less, on a 95 per cent probability basis.*

Note 1.— This is the equipment error, and does not include any propagation effects.

Note 2.— Guidance on the measurement of this parameter can be found in Attachment G, 2.5.2.

3.11.5.2.6 *Siting*

Note 1.— It is not intended to restrict the installation of MLS when it is not possible to site the azimuth ground equipment on the extension of the runway centre line.

Note 2.— Guidance material on critical and sensitive areas for azimuth antennas is provided in Attachment G, 4.3.

3.11.5.2.6.1 Normally, the approach azimuth ground equipment antenna shall be located on the extension of the runway centre line beyond the stop end and shall be adjusted so that the vertical plane containing the zero degree course line will contain the MLS approach reference datum. Siting of the antenna shall be consistent with safe obstacle clearance SARPs in Annex 14.

3.11.5.2.6.2 The back azimuth ground equipment antenna shall normally be located on the extension of the runway centre line at the threshold end, and the antenna shall be adjusted so that the vertical plane containing the zero degree course line will contain the back azimuth reference datum.

3.11.5.3 *Elevation guidance equipment*

3.11.5.3.1 *Scanning beam characteristics.* The elevation ground equipment antenna shall produce a fan-shaped beam that is narrow in the vertical plane, broad in the horizontal plane and which is scanned vertically between the limits of the proportional guidance sector.

3.11.5.3.1.1 *Coordinate system.* Approach elevation guidance information shall be radiated in conical coordinates.

3.11.5.3.1.2 *Antenna beamwidth.* The antenna beamwidth shall not exceed 2.5 degrees.

3.11.5.3.1.3 *Scanning beam shape.* The minus 10-dB points on the beam envelope shall be displayed from the centre line by at least 0.76 beamwidth but not more than 0.96 beamwidth.

Note.— The beam shape described applies on boresight in a multipath-free environment using a suitable filter. Information on beam shape and side lobes is provided in Attachment G, 3.1 and 3.2.

3.11.5.3.2 *Coverage*

Note.— Diagrams illustrating the coverage requirements specified herein are contained in Attachment G, Figure G-10A.

3.11.5.3.2.1 *Approach elevation.* Except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation ground equipment shall provide proportional guidance information in at least the following volume of space:

3.11.5.3.2.1.1 *Approach region.*

a) Laterally, within a sector originating at the elevation antenna phase centre which has an angular extent at least equal to the proportional guidance sector provided by the approach azimuth ground equipment at the longitudinal coverage limit.

b) Longitudinally, from the elevation antenna in the direction of the approach to 37 km (20 NM) from threshold.

c) Vertically, between:

1) a lower conical surface originating at the elevation antenna phase centre and inclined upward to reach, at the longitudinal coverage limit, a height of 600 m (2 000 ft) above the horizontal plane which contains the antenna phase centre; and

2) an upper conical surface originating at the elevation antenna phase centre and inclined 7.5 degrees above the horizontal up to a height of 6 000 m (20 000 ft).

Note.— When the physical characteristics of the approach region prevent the achievement of the Standards under a), b) and c) 1), it is intended that guidance need not be provided below the line of sight.

3.11.5.3.2.1.1.1 **Recommendation.—** *The approach elevation ground equipment should provide proportional guidance to angles greater than 7.5 degrees above the horizontal when necessary to meet operational requirements.*

3.11.5.3.2.1.2 *Minimum operational coverage region.*

a) Laterally, within a sector originating at the MLS datum point, of plus and minus 10 degrees about the runway centre line;

b) Longitudinally, 75 m (250 ft) from the MLS datum point in the direction of threshold, to the far coverage limit specified in 3.11.5.3.2.1.1 b);

c) Vertically, between the upper surface specified in 3.11.5.3.2.1.1 c) 2), and the higher of:

1) a surface which is the locus of points 2.5 m (8 ft) above the runway; or

2) a plane originating at the MLS datum point and inclined upward to reach, at the longitudinal coverage limit, the height of the surface specified in 3.11.5.3.2.1.1 c) 1).

Note.— Information related to the horizontal radiation pattern of the approach elevation is provided in Attachment G, 3.3.

3.11.5.3.3 *Monitor and control*

3.11.5.3.3.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation monitor system shall cause the radiation of its respective functions to cease and a warning shall be provided at the designated control point if any of the following conditions persist for longer than the periods specified:

a) there is a change in the ground equipment contribution to the mean glide path error component such that the PFE at the approach reference datum or on any glide path consistent with published approach procedures exceeds the limits specified in 3.11.4.9.6 for a period of more than one second;

b) there is a reduction in the radiated power to less than that necessary to satisfy the requirements specified in 3.11.4.10.1 for a period of more than one second;

c) there is an error in the preamble DPSK transmissions which occurs more than once in any one-second period;

d) there is an error in the TDM synchronization of a particular elevation function such that the requirement specified in 3.11.4.3.2 is not satisfied and this condition persists for more than one second.

Note.— Guidance material is provided in Attachment G, 6.

3.11.5.3.3.2 Design and operation of the monitor system shall cause radiation to cease and a warning shall be provided at the designated control points in the event of failure of the monitor system itself.

3.11.5.3.3.3 The period during which erroneous guidance information is radiated, including period(s) of zero radiation, shall not exceed the periods specified in 3.11.5.3.3.1. Any attempts to clear a fault by resetting the primary ground equipment or by switching to standby ground equipment shall be completed within this time, and any period(s) of zero radiation shall not exceed 500 milliseconds. If the fault is not cleared within the time allowed, radiation shall cease. After shutdown, no attempt shall be made to restore service until a period of 20 seconds has elapsed.

3.11.5.3.4 *Integrity and continuity of service requirements for MLS approach elevation*

3.11.5.3.4.1 The probability of not radiating false guidance signals shall not be less than $1 - 0.5 \times 10^{-9}$ in any one landing for an MLS approach elevation intended to be used for Categories II and III operations.

3.11.5.3.4.2 **Recommendation.—** *The probability of not radiating false guidance signals should not be less than $1 - 1.0 \times 10^{-7}$ in any one landing on MLS approach elevation intended to be used for Category I operations.*

3.11.5.3.4.3 The probability of not losing the radiated guidance signal shall be greater than $1 - 2 \times 10^{-6}$ in any period of 15 seconds for an MLS approach elevation intended to be used for Categories II and III operations (equivalent to 2 000 hours mean time between outages).

3.11.5.3.4.4 **Recommendation.—** *The probability of not losing the radiated guidance signal should exceed $1 - 4 \times 10^{-6}$ in any period of 15 seconds for an MLS approach elevation intended to be used for Category I operations (equivalent to 1 000 hours mean time between outages).*

Note.— Guidance material on integrity and continuity of service is given in Attachment G, 11.

3.11.5.3.5 *Ground equipment accuracy*

3.11.5.3.5.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the ground equipment contribution to the mean glide path error component of the PFE shall not exceed an error equivalent to plus or minus 0.3 m (1 ft) at the approach reference datum.

3.11.5.3.5.2 **Recommendation.—** *The ground equipment contribution to the CMN at the reference datum should not exceed 0.15 m (0.5 ft) on a 95 per cent probability basis.*

Note 1.— This is the equipment error, and does not include any propagation effects.

Note 2.— Guidance on the measurement of this parameter can be found in Attachment G, 2.5.2.

3.11.5.3.6 *Siting*

Note.— Guidance material on critical areas for elevation antennas is provided in Attachment G, 4.2.

3.11.5.3.6.1 The approach elevation ground equipment antenna shall be located beside the runway. Siting of the antennas shall be consistent with obstacle clearance Standards and Recommended Practices in Annex 14.

3.11.5.3.6.2 The approach elevation ground equipment antenna shall be sited so that the asymptote of the minimum glide path crosses the threshold at the MLS approach reference datum.

3.11.5.3.6.2.1 **Recommendation.—** *The minimum glide path angle is normally 3 degrees and should not exceed 3 degrees except where alternative means of satisfying obstacle clearance requirements are impractical.*

Note.— It is intended that the choice of a minimum glide path angle higher than 3 degrees be determined by operational rather than technical factors.

3.11.5.3.6.2.2 **Recommendation.—** *The approach elevation ground equipment antenna should be sited so that the height of the point which corresponds to the decoded guidance signal of the minimum glide path above the threshold does not exceed 18 m (60 ft).*

Note.— The offset of the elevation antenna from the runway centre line will cause the minimum glide path elevation guidance to be above the approach reference datum.

3.11.5.3.6.3 **Recommendation.—** *When ILS and MLS simultaneously serve the same runway, the ILS reference datum and the MLS approach reference datum should coincide within a tolerance of 1 m (3 ft).*

Note 1.— It is intended that this recommendation would apply only if the ILS reference datum satisfies the height specifications in 3.1.5.1.4 and 3.1.5.1.5.

Note 2.— Information related to collocated MLS/ILS siting is provided in Attachment G, 4.1.

3.11.5.4 *Data coverage and monitoring*

Note 1.— Guidance material relating to data applications is provided in Attachment G, 2.7.

Note 2.— The essential data are basic data and essential auxiliary data transmitted in auxiliary data words A1, A2, A3 and A4.

3.11.5.4.1 *Basic data*

3.11.5.4.1.1 The basic data words 1, 2, 3, 4 and 6 shall be transmitted throughout the approach azimuth coverage sector.

Note.— The composition of the basic data words is given in Appendix A, Table A-7.

3.11.5.4.1.2 Where the back azimuth function is provided, basic data words 4, 5 and 6 shall be transmitted throughout the approach azimuth and back azimuth coverage sectors.

3.11.5.4.2 *Auxiliary data*

3.11.5.4.2.1 Auxiliary data words A1, A2 and A3 shall be transmitted throughout the approach azimuth coverage sector.

3.11.5.4.2.2 Where the back azimuth function is provided, auxiliary data words A3 and A4 shall be transmitted throughout the approach azimuth and back azimuth coverage sectors.

Note.— Auxiliary data words B42 and B43 are transmitted in place of A1 and A4, respectively, to support applications which require azimuth antenna rotation beyond the alignment range available in A1 and A4.

3.11.5.4.2.3 When provided, auxiliary data B words shall be transmitted throughout the approach azimuth sector, except that the words comprising the back azimuth procedure database shall be transmitted throughout the back azimuth sector.

3.11.5.4.2.4 **Recommendation.—** *If the back azimuth function is provided, the appropriate auxiliary data B words should be transmitted.*

Note.— The composition of the auxiliary data words is given in Appendix A, Tables A-10, A-12 and A-15.

3.11.5.4.3 *Monitor and control*

3.11.5.4.3.1 The monitor system shall provide a warning to the designated control point if the radiated power is less than that necessary to satisfy the DPSK requirement specified in 3.11.4.10.1.

3.11.5.4.3.2 If a detected error in the basic data radiated into the approach azimuth coverage occurs in at least two consecutive samples, radiation of these data, approach azimuth and elevation functions shall cease.

3.11.5.4.3.3 If a detected error in the basic data radiated into the back azimuth coverage occurs in at least two consecutive samples, radiation of these data and the back azimuth function shall cease.

3.11.5.5 *Distance measuring equipment*

3.11.5.5.1 DME information shall be provided at least throughout the coverage volume in which approach and back azimuth guidance is available.

3.11.5.5.2 **Recommendation.—** *DME information should be provided throughout 360° azimuth if operationally required.*

Note.— Siting of DME ground equipment is dependent on runway length, runway profile and local terrain. Guidance on siting of DME ground equipment is given in Attachment C, 7.1.6 and Attachment G, 5.

3.11.6 Airborne equipment characteristics

3.11.6.1 *Angle and data functions*

3.11.6.1.1 *Accuracy*

3.11.6.1.1.1 Where the DPSK and scanning beam signal power densities are the minimum specified in 3.11.4.10.1, the airborne equipment shall be able to acquire the signal and any decoded angle signal shall have a CMN not exceeding 0.1 degree, except that the back azimuth guidance function CMN shall not exceed 0.2 degree.

Note 1.— It is intended that basic and auxiliary data words which contain information essential for the desired operation be decoded within a time period and with an integrity which is suitable for the intended application.

Note 2.— Information related to the acquisition and validation of angle guidance and data functions is given in Attachment G, 7.3.

3.11.6.1.1.2 Where the radiated signal power density is high enough to cause the airborne receiver noise contribution to be insignificant, the airborne equipment shall not degrade the accuracy of any decoded angle guidance signal by greater than plus or minus 0.017 degree (PFE), and plus or minus 0.015 degree (azimuth), and plus or minus 0.01 degree (elevation) CMN.

3.11.6.1.1.3 In order to obtain accurate guidance to 2.5 m (8 ft) above the runway surface, the airborne equipment shall produce less than 0.04 degree CMN with the power densities indicated in 3.11.4.10.2 b).

3.11.6.1.2 *Dynamic range*

3.11.6.1.2.1 The airborne equipment shall be able to acquire the signal and the performance in 3.11.6.1.1.2 shall be met where the power density of any of the radiated signals has any value between the minimum specified in 3.11.4.10.1 up to a maximum of minus 14.5 dBW/m^2.

3.11.6.1.2.2 The receiver performance shall not degrade beyond the specified limits when the maximum differential levels permitted in 3.11.6.1.2.1 exist between signal power densities of individual functions.

3.11.6.1.3 *Receiver angle data output filter characteristics*

3.11.6.1.3.1 For sinusoidal input frequencies, receiver output filters shall not induce amplitude variations or phase lags in the angle data which exceed those obtained with a single pole low-pass filter with a corner frequency of 10 rad/s by more than 20 per cent.

Note.— Receiver outputs intended only to operate visual displays may benefit from appropriate additional filtering. Additional information on output data filtering is given in Attachment G, 7.4.2.

3.11.6.1.4 *Adjacent channel spurious response.* The receiver performance specified in 3.11.6 shall be met when the ratio between the desired tracked signals and the noise produced by the adjacent channel signals in a 150 kHz bandwidth centred around the desired frequency is equal to or greater than the signal-to-noise ratio (SNR) values:

a) as specified in Table X1 when the power density received from the desired ground station is equal to or higher than the values as specified in Table Y, or

b) as specified in the Table X2 when the power density received from the desired ground station is between the minimum density power values specified in 3.11.4.10.1 and the values specified in Table Y.

Table Y

	Beam width (Note 2)		
Function	*1°*	*2°*	*3°*
Approach azimuth guidance	–69.8 dBW/m^2	–63.8 dBW/m^2	–60.2 dBW/m^2
High rate approach azimuth guidance	–74.6 dBW/m^2	–69.5 dBW/m^2	–65 dBW/m^2
Approach elevation guidance	–71 dBW/m^2	–65 dBW/m^2	N/A
Back azimuth	N/A (Note 4)	N/A (Note 4)	N/A (Note 4)

Table X1

		SNR (Note 1) *Beam width (Note 2)*		
Function	*Data*	*1°*	*2°*	*3°*
Approach azimuth guidance	5 dB	24.7 dB	30.7 dB	34.3 dB
High rate approach azimuth guidance	5 dB	19.9 dB	26 dB	29.5 dB
Approach elevation guidance	5 dB	23.5 dB	29.5 dB	N/A
Back azimuth (Note 4)	5 dB	5.2 dB	11.2 dB	14.8 dB

Table X2

		SNR (Note 1)		
		Beam width (Note 2)		
Function	*Data*	*1°*	*2°*	*3°*
Approach azimuth guidance	5 dB	8.2 dB	14.3 dB	17.8 dB
High rate approach azimuth guidance	5 dB	3.5 dB	9.5 dB	13 dB
Approach elevation guidance	5 dB	3.5 dB	9.5 dB	N/A
Back azimuth (Note 4)	5 dB	5.2 dB	11.2 dB	14.8 dB

Note 1.— When the radiated desired signal power density is high enough to cause the airborne receiver noise contribution to be insignificant, the airborne CMN contribution for elevation and approach azimuth guidance (not for back azimuth) is required as stated in 3.11.6.1.1, to be reduced compared to the CMN contribution when the radiated desired signal power density is at the minimum specified in 3.11.4.10.1 and the minimum SNR values are therefore higher.

Note 2.— The relationship is linear between adjacent points designated by the beam widths.

Note 3.— These SNR values are to be protected through application of frequency separation criteria as explained in Attachment G, 9.3.

Note 4.— As there is no change in back azimuth guidance accuracy when the airborne receiver noise may be considered as insignificant, the same SNR values are applied for back azimuth.

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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

c) satellite data measurement blocks.

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

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

3.6.4.2.3 Pseudo-range correction parameters shall be as follows:

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

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

Additional message flag: an identification of whether the set of measurement blocks in a single frame for a particular measurement type is contained in a single Type 1 message or a linked pair of messages.

Coding: 0 = All measurement blocks for a particular measurement type are contained in one Type 1 message.
1 = This is the first transmitted message of a linked pair of Type 1 messages that together contain the set of all measurement blocks for a particular measurement type.
2 = Spare
3 = This is the second transmitted message of a linked pair of Type 1 messages that together contain the set of all measurement blocks for a particular measurement type.

Note.— When a linked pair of Type 1 messages is used for a particular measurement type, the number of measurements and low-frequency data are computed separately for each of the two individual messages.

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

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

Table B-63. GBAS VHF data broadcast messages

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

Note.— See 3.6.6 for message formats.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Coding: 1111 1110 = The duration is greater than or equal to 2 540 seconds.
1111 1111 = Prediction of source availability duration is not provided by this ground subsystem.

3.6.4.2.4 The measurement block parameters shall be as follows:

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

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

1. Introduction

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

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

Definitions relating to the Instrument Landing System (ILS)

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

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

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

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

2. Material concerning ILS installations

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

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

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

Category II operation: A precision instrument approach and landing with a decision height lower than 60 m (200 ft) but not lower than 30 m (100 ft), and a runway visual range not less than 350 m.

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

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

b) a runway visual range not less than 200 m.

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

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

b) a runway visual range less than 200 m but not less than 50 m.

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

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

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

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

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

2.1.2.4 The ILS classification scheme provides a means to make known the additional capabilities that may be available from a particular ILS ground facility, beyond those associated with the facilities defined in Chapter 3, 3.1.1. These additional capabilities can be exploited in order to permit operational use according to 2.1.2.1 and 2.1.2.2 to be approved down to and below the values stated in the operational objectives described in 2.1.1.

2.1.2.5 An example of the classification system is presented in 2.14.3.

Note.— The following guidance material is intended to assist States when they are evaluating the acceptability of ILS localizer courses and glide paths having bends. Although, by definition, course bends and glide path bends are related to the nominal positions of the localizer course and glide path respectively, the evaluation of high frequency aberrations is based on the deviations from the mean course or path. The material in 2.1.5 and Figure C-2 regarding the evaluation of bends indicates how the bends relate to the mean position of the course and path. Aircraft recordings will normally be in this form.

2.1.3 *Course bends.* Localizer course bends should be evaluated in terms of the course structure specified in Chapter 3, 3.1.3.4. With regard to landing and rollout in Category III conditions, this course structure is based on the desire to provide adequate guidance for manual and/or automatic operations along the runway in low visibility conditions. With regard to Category I performance in the approach phase, this course structure is based on the desire to restrict aircraft deviations, due to course bends (95 per cent probability basis) at the 30 m (100 ft) height, to lateral displacement of less than 10 m (30 ft). With regard to Categories II and III performance in the approach phase, this course structure is based on the desire to restrict aircraft deviations due to course bends (95 per cent probability basis) in the region between ILS Point B and the ILS reference datum (Category II facilities) or Point D (Category III facilities), to less than 2 degrees of roll and pitch attitude and to lateral displacement of less than 5 m (15 ft).

Note 1.— Course bends are unacceptable when they preclude an aircraft under normal conditions from reaching the decision height in a stable attitude and at a position, within acceptable limits of displacement from the course line, from which a safe landing can be effected. Automatic and semi-automatic coupling is affected to a greater degree than manual coupling by the presence of bends. Excessive control activity after the aircraft has settled on an approach may preclude it from satisfactorily completing an approach or landing. Additionally, when automatic coupling is used, there may be an operational requirement to continue the approach below the decision height. Aircraft guidance can be satisfied if the specification for course structure in Chapter 3, 3.1.3.4, is met.

Note 2.— Bends or other irregularities that are not acceptable will normally be ascertained by flight tests in stable air conditions requiring precision flight check techniques.

2.1.4 *ILS glide path bends.* Bends should be evaluated in terms of the ILS glide path structure specified in Chapter 3, 3.1.5.4. With regard to Category I performance, this glide path structure is based on the desire to restrict aircraft deviations due to glide path bends (95 per cent probability basis) at the 30 m (100 ft) height, to vertical displacements of less than 3 m (10 ft). With regard to Categories II and III performance, this glide path structure is based on the desire to restrict aircraft deviations due to path bends (95 per cent probability basis) at the 15 m (50 ft) height, to less than 2 degrees of roll and pitch attitude and to vertical displacements of less than 1.2 m (4 ft).

Note 1.— Path bends are unacceptable when they preclude an aircraft under normal conditions from reaching the decision height in a stable attitude and at a position, within acceptable limits of displacement from the ILS glide path, from which a safe landing can be effected. Automatic and semi-automatic coupling is affected to a greater degree than manual coupling by the presence of bends. Additionally, when automatic coupling is used, there may be an operational requirement to continue the approach below the decision height. Aircraft guidance can be satisfied if the specification for ILS glide path structure in Chapter 3, 3.1.5.4, is met.

Note 2.— Bends or other irregularities that are not acceptable will normally be ascertained by precision flight tests, supplemented as necessary by special ground measurements.

2.1.5 *Application of localizer course/glide path bend amplitude Standard.* In applying the specification for localizer course structure (Chapter 3, 3.1.3.4) and ILS glide path structure (Chapter 3, 3.1.5.4), the following criteria should be employed:

— Figure C-1 shows the relationship between the maximum (95 per cent probability) localizer course/glide path bend amplitudes and distances from the runway threshold that have been specified for Categories I, II and III performance.

— If the bend amplitudes are to be evaluated in any region of the approach, the flight recordings, corrected for aircraft angular position error, should be analysed for a time interval of plus or minus 20 seconds about the midpoint of the region to be evaluated. The foregoing is based on an aircraft ground speed of 195 km/h (105 knots) plus or minus 9 km/h (5 knots).

The 95 per cent maximum amplitude specification is the allowable percentage of total time interval in which the course/path bend amplitude must be less than the amount specified in Figure C-1 for the region being evaluated. Figure C-2 presents a typical example of the method that can be employed to evaluate the course/path bend amplitude at a particular facility. If the sum of the time intervals t_1, t_2, t_3, where the given specification is exceeded, is equal to or less than 5 per cent of the total time T, the region that is being evaluated is acceptable. Therefore:

$$100 \quad \frac{T - [(t_1 + t_2 + ...)]}{T} \geq 95\%$$

Analysis of ILS glide path bends should be made using as a datum the mean glide path and not the downward extended straight line. The extent of curvature is governed by the offset displacement of the ground equipment glide path antenna system, the distance of this antenna system from the threshold, and the relative heights of the ground along the final approach route and at the glide path site (see 2.4).

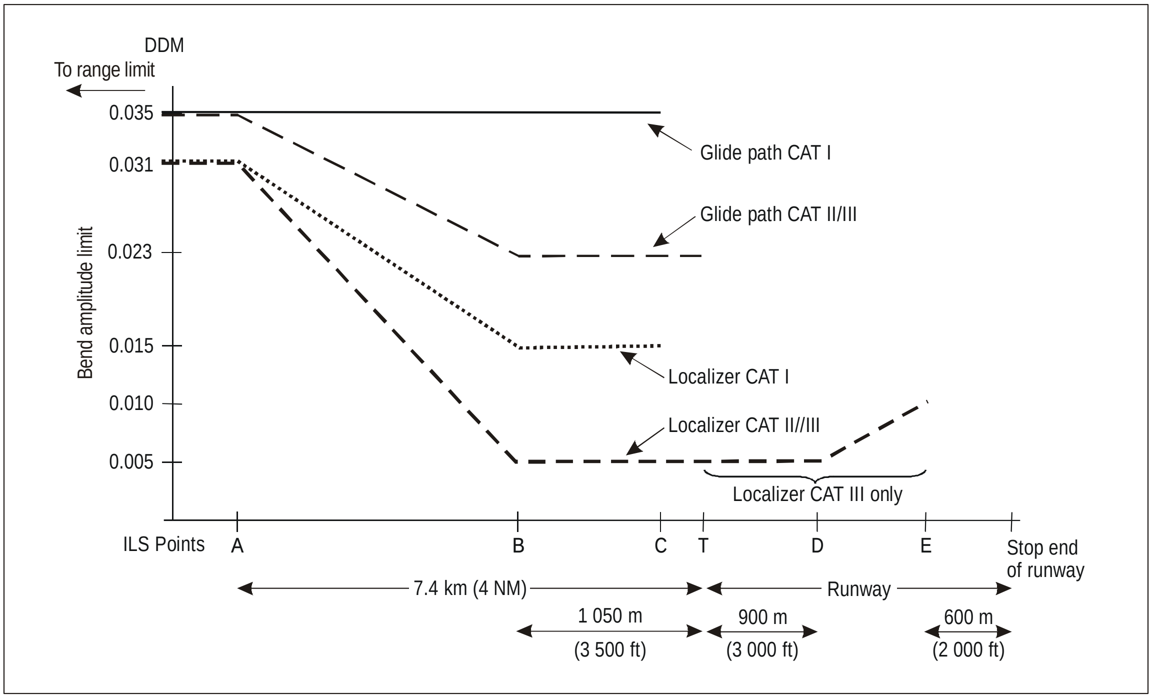
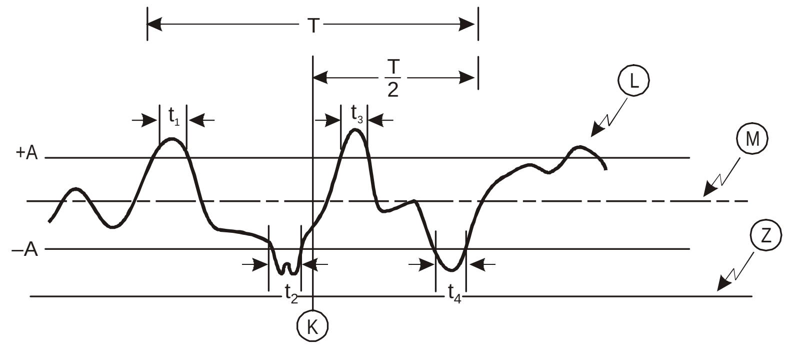


Figure C-1. Localizer course and glide path bend amplitude limits



(Z) = Zero Reference (Zero of measuring system)

(L) = Position corrected sample of course/path

(M) = Mean value of course/path

T = Region to be evaluated (± 20 seconds wide)

A = Bend amplitude limit according to Figure C-1 in reference to (M) applicable at (K)

(K) = Midpoint of an evaluation period

t_1, t_2, t_3... = Time intervals that bends exceed allowable limits
For the facility to be acceptable in this region:

$$100\ \frac{[T - (t_1 + t_2 + t_3 \ldots)]}{T} \geq 95\%$$

Figure C-2. Evaluation of course/path bend amplitude

2.1.6 *Measurements filter*. Owing to the complex frequency components present in the ILS beam bend structures, measured values of beam bends are dependent on the frequency response of the airborne receiving and recording equipment. It is intended that beam bend measurements be obtained by using a low-pass filter corner frequency (radians per second) for the receiver DDM output circuits and associated recording equipment of V/92.6, where V is the velocity in km/h of the aircraft or ground vehicle as appropriate.

2.1.7 *Monitor systems.* Available evidence indicates that performance stability within the limits defined in Chapter 3, 3.1.3.6, 3.1.3.7 and 3.1.5.6, i.e. well within the monitor limit, can readily be achieved.

2.1.7.1 The choice of monitor limits is based on judgement, backed by knowledge of the safety requirements for the category of operation. However, the specifications of such monitoring limits do not indicate the magnitude of the normal day-to-day variations in performance which result from setting-up errors and equipment drift. It is necessary to investigate and take corrective action if the day-to-day performance frequently drifts beyond the limits specified in Chapter 3, 3.1.3.6, 3.1.3.7 and 3.1.5.6. The causes of such drifts should be eliminated:

a) to reduce greatly the possibility of critical signal parameters hovering near the specified monitor limits;

b) to ensure a high continuity of ILS service.

2.1.7.2 Following are some general guidelines for the design, operation and maintenance of monitor systems to meet the requirements in Chapter 3, 3.1.3.11 and 3.1.5.7.

1) Great care should be exercised to ensure that monitor systems respond to all those variations of the ground facility which adversely affect the operation of the airborne system during ILS approach.

2) Monitor systems should not react to local conditions which do not affect the navigational information as seen by airborne systems.

3) Drifts of the monitor system equipment should not appreciably reduce or increase the monitoring limits specified.

4) Special care must be taken in the design and operation of the monitor system with the aim of ensuring that the navigational components will be removed or radiation cease in the event of a failure of the monitor system itself.

5) Some monitors rely on devices which sample the signal in the vicinity of the transmitter antenna system. Experience has shown that such monitor systems require special attention in the following aspects:

   a) where large-aperture antenna systems are used, it is often not possible to place the monitor sensors in such a position that the phase relationship observed in the far field on the course exists at the sensing point. Nevertheless, the monitor system should also detect antenna and associated feeder system changes which significantly affect the course in the far field;

   b) changes in effective ground level caused by snow, flooding, etc., may affect glide path monitor systems, and the actual course in space differently, particularly when reliance is placed on the ground plane to form the desired glide path pattern;

   c) attention should be paid to other causes which may disturb the monitor sensing of the radiated signal, such as icing and birds;

   d) in a system where monitoring signals are used in a feedback loop to correct variations of the corresponding equipment, special care should be taken that extraneous influence and changes in the monitor system itself do not cause course or ILS glide path variations outside the specified limits without alarming the monitor.

6) One possible form of monitor is an integral monitor in which the contribution of each transmitting antenna element to the far-field course signal is measured at the antenna system. Experience has shown that such monitoring systems, properly designed, can give a close correlation between the monitor indication and the radiated signal in the far field. This type of monitor, in certain circumstances, overcomes the problem outlined in 5) a), b) and c).

2.1.7.3 It will be realized that the DDM measured at any one point in space is a function of displacement sensitivity and the position of the course line or ILS glide path. This should be taken into account in the design and operation of monitor systems.

2.1.8 *Radiation by ILS localizers not in operational use.* Severe interference with operational ILS localizer signals has been experienced in aircraft carrying out approaches to low levels at runways equipped with localizer facilities serving the reciprocal direction to the approach. Interference in aircraft overflying this localizer antenna system is caused by cross modulation due to signals radiated from the reciprocal approach localizer. Such interference, in the case of low level operations, could seriously affect approach or landing, and may prejudice safety. Chapter 3, 3.1.2.7, 3.1.2.7.1 and 3.1.2.7.2 specify the conditions under which radiation by localizers not in operational use may be permitted.

2.1.9 *ILS multipath interference*

Note.— This guidance material does not consider how new large aircraft impact the sizes of critical and sensitive areas. It is being updated to consider the effect on the critical and sensitive areas of such aircraft, and of the considerable changes in airport and operational environment since the first development of the material. States are urged to use caution in applying the examples described below, as they do not consider several factors that impact quality of signal-in-space.

2.1.9.1 The occurrence of interference to ILS signals is dependent on the total environment around the ILS antennas, and the antenna characteristics. Any large reflecting objects, including vehicles or fixed objects such as structures within the radiated signal coverage, will potentially cause multipath interference to the ILS course and path structure. The location and size of the reflecting fixed objects and structures in conjunction with the directional qualities of the antennas will determine the static course or path structure quality whether Category I, II or III. Movable objects can degrade this structure to the extent that it becomes unacceptable. The areas within which this degradable interference is possible need to be defined and recognized. For the purposes of developing protective zoning criteria, these areas can be divided into two types, i.e. critical areas and sensitive areas:

a) the ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space;

b) the ILS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.

Note 1.— The objective of defining critical and sensitive areas is to afford adequate protection to the ILS. The manner in which the terminology is applied may vary between States. In some States, the term "critical area" is also used to describe the area that is referred to herein as the sensitive area.

Note 2.— It is expected that at sites, where ILS and MLS are to be collocated, the MLS might be located within ILS critical areas in accordance with guidance material in Attachment G, 4.1.

2.1.9.2 Typical examples of critical and sensitive areas that need to be protected are shown in Figures C-3A, C-3B, C-4A and C-4B. To protect the critical area, it is necessary to normally prohibit all entry of vehicles and the taxiing or parking of aircraft within this area during all ILS operations. The critical area determined for each localizer and glide path should be clearly designated. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical area to restrict the entry of vehicles and aircraft. With respect to sensitive areas, it may be necessary to exclude some or all moving traffic depending on interference potential and category of operation. It would be advisable to have the aerodrome boundaries include all the sensitive areas so that adequate control can be exercised over all moving traffic to prevent unacceptable interference to the ILS signals. If these areas fall outside the aerodrome boundaries, it is essential that the cooperation of appropriate authorities be obtained to ensure adequate control. Operational procedures need to be developed for the protection of sensitive areas.

2.1.9.3 The size of the sensitive area depends on a number of factors including the type of ILS antenna, the topography, and the size and orientation of man-made objects, including large aircraft and vehicles. Modern designs of localizer and glide path antennas can be very effective in reducing the disturbance possibilities and hence the extent of the sensitive areas. Because of the greater potential of the larger types of aircraft for disturbing ILS signals, the sensitive areas for these aircraft extend a considerable distance beyond the critical areas. The problem is aggravated by increased traffic density on the ground.

2.1.9.3.1 In the case of the localizer, any large objects illuminated by the main directional radiation of the antenna must be considered as possible sources of unacceptable signal interference. This will include aircraft on the runway and on some taxiways. The dimensions of the sensitive areas required to protect Category I, II and III operations will vary, the largest being required for Category III. Only the least disturbance can be tolerated for Category III, but an out-of-tolerance course along the runway surface would have no effect on Category I or II operations. If the course structure is already marginal due to static multipath effects, less additional interference will cause an unacceptable signal. In such cases a larger-size sensitive area may have to be recognized.

2.1.9.3.2 In the case of the glide path, experience has shown that any object penetrating a surface above the reflection plane of the glide path antenna and within azimuth coverage of the antenna must be considered as a source of signal interference. The angle of the surface above the horizontal plane of the antenna is dependent on the type of glide path antenna array in use at the time. Very large aircraft, when parked or taxiing within several thousand feet of the glide path antenna and directly between it and the approach path, will usually cause serious disturbance to the glide path signal. On the other hand, the effect of small aircraft beyond a few hundred feet of the glide path antenna has been shown to be negligible.

2.1.9.3.3 Experience has shown that the major features affecting the reflection and diffraction of the ILS signal to produce multipath interference are the height and orientation of the vertical surfaces of aircraft and vehicles. The maximum height of vertical surface likely to be encountered must be established, together with the “worst case” orientation. This is because certain orientations can cause out-of-tolerance localizer or glide path deviations at greater distances than parallel or perpendicular orientations.

2.1.9.4 Computer or model techniques can be employed to calculate the probable location, magnitude and duration of ILS disturbances caused by objects, whether by structures or by aircraft of various sizes and orientation at different locations. Issues involved with these techniques include the following:

a) computerized mathematical models are in general use and are applied by personnel with a wide variety of experience levels. However, engineering knowledge of and judgement about the appropriate assumptions and limitations are required when applying such models to specific multipath environments. ILS performance information relative to this subject should normally be made available by the ILS equipment manufacturer;

b) where an ILS has been installed and found satisfactory, computers and simulation techniques can be employed to predict the probable extent of ILS disturbance which may arise as a result of proposed new construction. Wherever possible, the results of such computer-aided simulation should be validated by direct comparison with actual flight measurements of the results of new construction; and

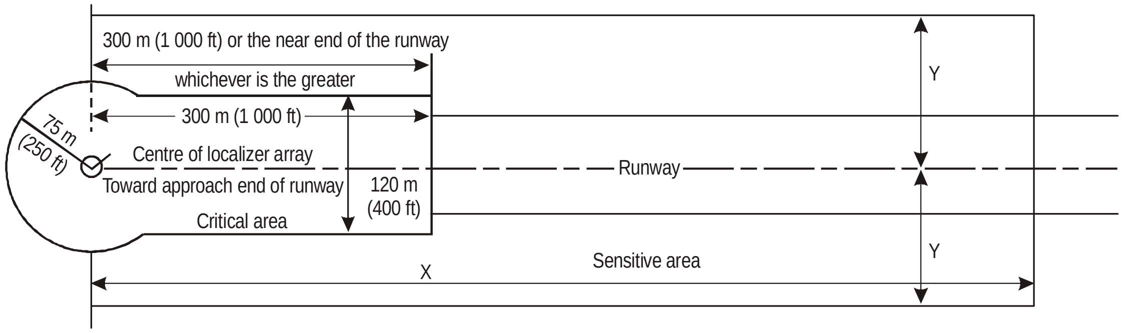
c) taking into account the maximum allowable multipath degradation of the signal due to aircraft on the ground, the corresponding minimum sensitive area limits can be determined. Models have been used to determine the critical and sensitive areas in Figures C-3A, C-3B, C-4A and C-4B, by taking into account the maximum allowable multipath degradation of ILS signals due to aircraft on the ground. The factors that affect the size and shape of the critical and sensitive areas include: aircraft types likely to cause interference, antenna aperture and type (log periodic dipole/dipole, etc.), type of clearance signals (single/dual frequency), category of operations proposed, runway length, and static bends caused by existing structures. Such use of models should involve their validation, which includes spot check comparison of computed results with actual field demonstration data on parked aircraft interference to the ILS signal.

2.1.9.5 Control of critical areas and the designation of sensitive areas on the airport proper may still not be sufficient to protect an ILS from multipath effects caused by large, fixed ground structures. This is particularly significant when considering the size of new buildings being erected for larger new aircraft and other purposes. Structures outside the boundaries of the airport may also cause difficulty to the ILS course quality, even though they meet restrictions with regard to obstruction heights.

2.1.9.5.1 Should the environment of an airport in terms of large fixed objects such as tall buildings cause the structure of the localizer and/or glide path to be near the tolerance limits for the category of operation, much larger sensitive areas may need to be established. This is because the effect of moving objects, which the sensitive areas are designed to protect the ILS against, has to be added to the static beam bends caused by fixed objects. However, direct addition of the maximum bend amplitudes is not considered appropriate and a root sum square combination is felt to be more realistic. Examples are as follows:

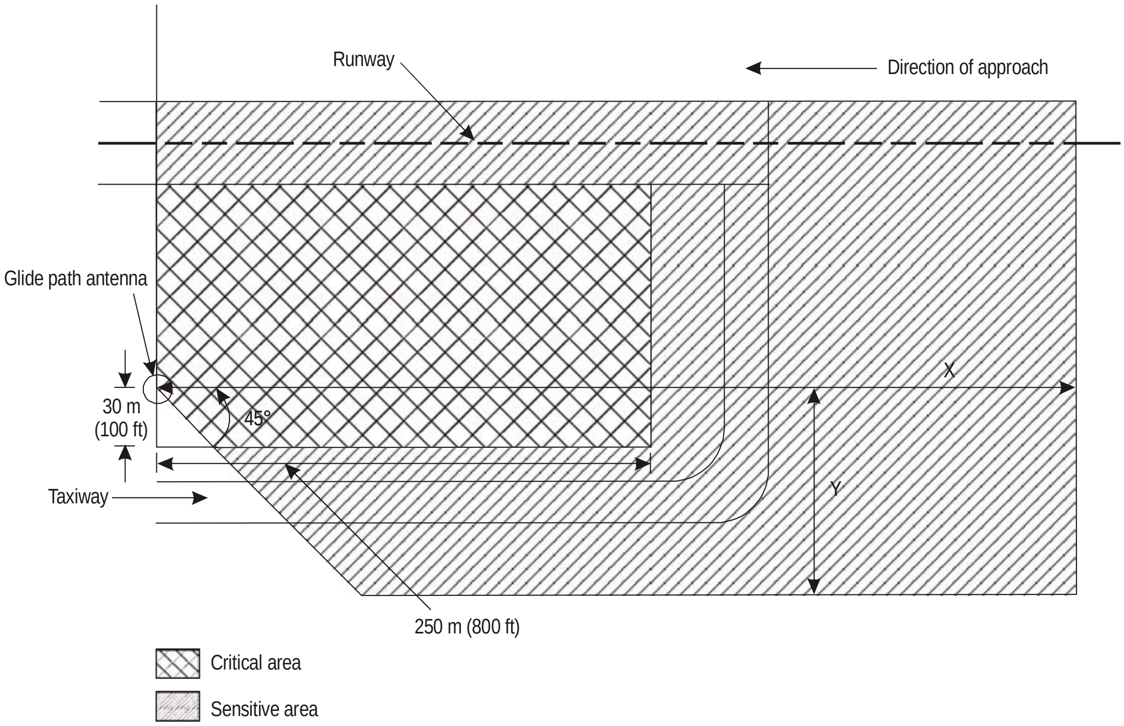
a) localizer course bends due to static objects equals plus or minus 1½µA. Limit plus or minus 5µA. Therefore allowance for moving objects to define localizer sensitive area is

$$\sqrt{5^2 - 1.5^2} = 4.77\mu A$$



		Example 1	*Example 2*	*Example 3*
Aircraft type		B-747	B-747	B-727
Localizer antenna aperture		Typically 27 m (90 ft) (Directional dual frequency, 14 elements)	Typically 16 m (50 ft) (Semi-directional, 8 elements)	Typically 16 m (50 ft) (Semi-directional, 8 elements)
Sensitive area (X, Y)				
Category I	X	600 m (2 000 ft)	600 m (2 000 ft)	300 m (1 000 ft)
	Y	60 m (200 ft)	110 m (350 ft)	60 m (200 ft)
Category II	X	1 220 m (4 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)
Category III	X	2 750 m (9 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)

Figure C-3A. Typical localizer critical and sensitive areas dimension variations for a 3 000 m (10 000 ft) runway



		Example 1	*Example 2*	*Example 3*
Aircraft type		B-747	B-727	small & medium*
Category I	X	915 m (3 000 ft)	730 m (2 400 ft)	250 m (800 ft)
	Y	60 m (200 ft)	30 m (100 ft)	30 m (100 ft)
Category II/III	X	975 m (3 200 ft)	825 m (2 700 ft)	250 m (800 ft)
	Y	90 m (300 ft)	60 m (200 ft)	30 m (100 ft)

* Small and medium aircraft here are considered as those having both a length less than 18 m (60 ft) and a height less than 6 m (20 ft).

Note.— In some cases the sensitive areas may be extended beyond the opposite side of the runway.

Figure C-3B. Typical glide path critical and sensitive areas dimension variations

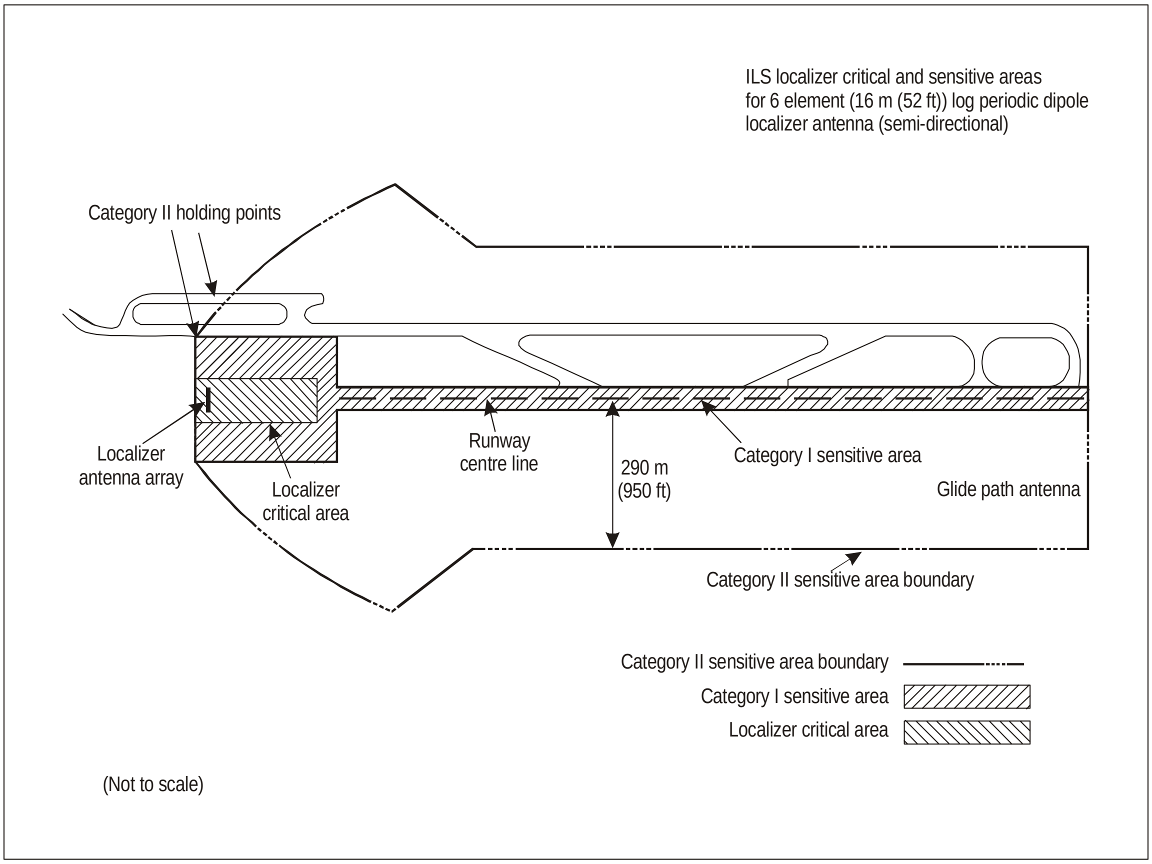


Figure C-4A. Example of critical and sensitive area application at specific sites with B-747 aircraft interference

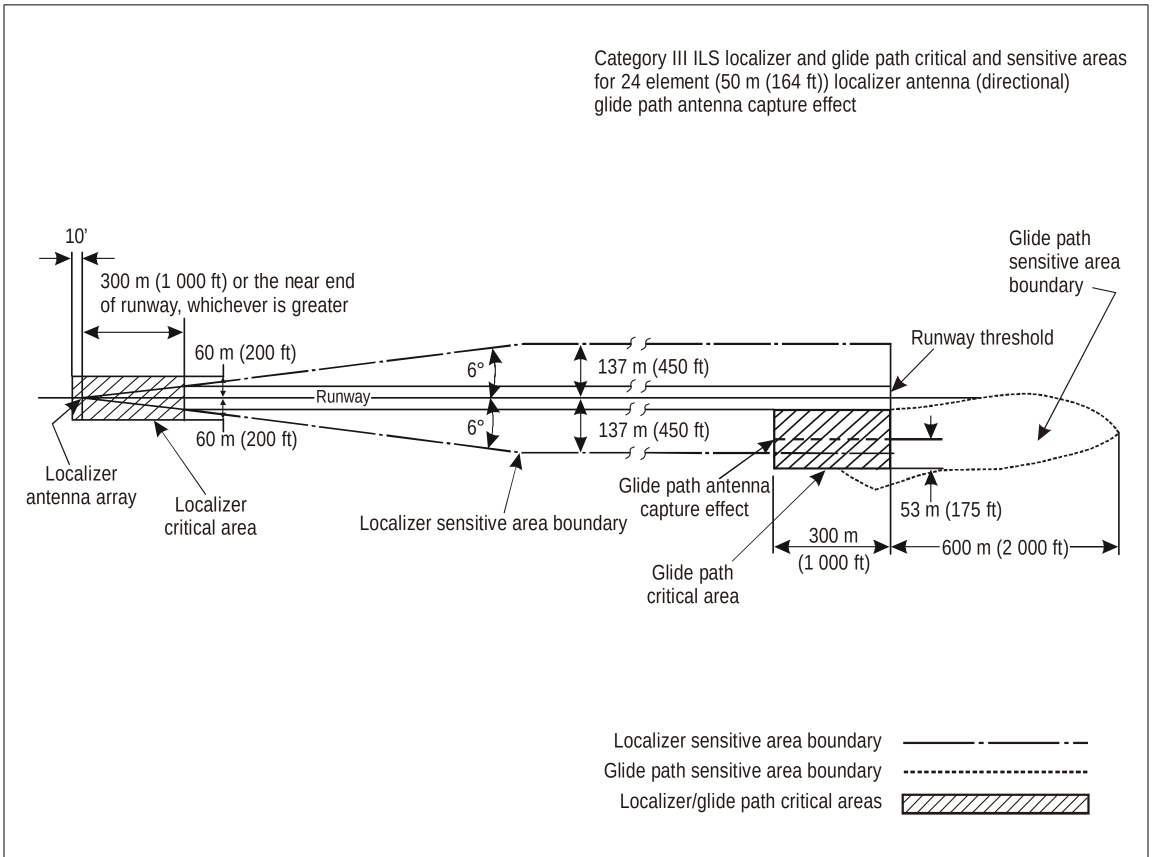


Figure C-4B. Example of critical and sensitive area application at specific sites with B-747 aircraft interference

b) localizer course bends due to static objects equals plus or minus 4μ*A*. Limit plus or minus 5μ*A*. Therefore allowance for moving objects to define localizer sensitive area is

$$\sqrt{5^2 - 4^2} = 3\mu A$$

In case b) the sensitive area would be larger, thus keeping interfering objects further away from the runway so that they produce 3μ*A* or less distortion of the localizer beam. The same principle is applied to the glide path sensitive area.

2.1.10 *Guidance on operational aspects of improving the performance of the ILS localizer in respect to bends*

2.1.10.1 *Introduction.* Owing to site effects at certain locations, it is not always possible to produce with simple standard ILS installations localizer courses that are sufficiently free from troublesome bends or irregularities. At such installations, it will often be possible to reduce bends and irregularities in the localizer course to a satisfactory extent by various methods, most of which require acceptance of some deviation from the specification for ILS set forth in this Annex, together with possible penalties from an operational aspect.

2.1.10.2 *Methods of effecting improvement.* In general, improvements in localizer courses from the aspect of bends or irregularities may be effected by restriction of radiation in particular directions so as to avoid or minimize reflection from objects that give rise to the bends. In the majority of instances where special treatment is required, this may be achieved by screens placed and designed to reduce the radiation in the direction of the object. Where reflecting objects are numerous or of large dimensions, however, it may be necessary to restrict almost all the radiation from the localizer to a narrow sector centred on the course line. Each method introduces certain disadvantages which should be weighed for the individual installation in the light of the specific operational application to be made of the installation and the following considerations.

2.1.10.3 *Disadvantages of methods of effecting improvements mentioned above*

2.1.10.3.1 The use of screens limiting radiation in selected directions will, in general, give rise to a reduction of the clearance between the two modulation signals of the ILS in some other direction, with the consequence that the ILS indicator needle may move towards the centre when the aircraft is passing through areas in that direction. It is considered however that, in general, such deviations are not operationally significant or may be overcome by suitable procedures. In certain applications including the use of screens or reflectors to reinforce signals in the course sector, the use of screens or reflectors will modify the range and characteristics of the back course of the localizer. Here again, it is considered that the effects are unlikely to be operationally significant unless operational use is being made of the back course. In this latter case, it may be necessary to provide an additional facility to supplement or replace the back course.

2.1.10.3.2 Where it is necessary to limit radiation from the localizer over a wide sector and confine most of it to a sector centred on the front course of the localizer in order to reduce bends sufficiently, the disadvantages will, in general, be as follows:

a) Orientation information from the localizer in the sector in which radiation is limited will no longer be available or will be unreliable.

b) It will not be practicable to carry out a preliminary check of the performance of the aircraft receiver through the flag system until the aircraft is within the sector centred on the course line.

c) In the area outside the sector centred on the course line, sufficient radiation may occur in particular directions to operate the ILS indicator in the aircraft in an erratic manner, giving rise to false indications.

d) The loss of the back course.

2.1.10.3.3 In respect to a), it is considered that orientation information is necessary but that practice has shown that such information is preferably obtained in any event from an auxiliary aid such as a locator. Such an auxiliary aid would be necessary if radiation from the localizer is confined to a narrow sector centred on the course line. In respect to b), it is considered that the loss of a receiver check prior to entry into the sector centred on the course line could be operationally accepted.

2.1.10.3.4 The disadvantage indicated in c) may, in some instances, be a serious drawback. In general, it is considered that acceptance of this disadvantage will depend on the extent to which false indications will occur at a particular site and on the procedures established or specified for the use of the ILS installation. In practice, it is possible to establish procedures so that no use is made of the localizer signals until the aircraft is able to check that it is in the usable sector. Experience has shown at one installation in operational use that, procedurally, no difficulty has arisen through the existence of erratic indications in the off-course sector. It is considered that the question of whether or not the off-course signal characteristics due to reduction of radiation in a narrow sector may be accepted operationally is a matter for individual assessment at each location concerned.

2.1.10.3.5 The loss of the back course indicated in d) may have several disadvantages. At some locations, the back course serves a useful function through intersection with other aids for facilitating procedures in the area concerned. Also, the back course often provides a useful aid in missed approach procedures and can often be used to simplify approach for landing when conditions require that the landing direction be opposite to the direction for which the ILS is primarily installed. Loss of the back course will, in general, require the provision of a substitute aid or aids, and the principal disadvantage in suppressing the back course may be considered in terms of the additional expense of a substitute aid or aids.

2.1.10.4 *Extent to which sector centred on course line may be narrowed.* It is considered that a radiation sector 10 degrees each side of the localizer course line would be the minimum sector that could be accepted operationally. It is desirable that the characteristics of the signal from the localizer be identical with those specified in Chapter 3 within the region in the immediate vicinity (region from DDMs 0.155 to zero) of the course line and approximate closely to them out to 10 degrees, so that the indications of the ILS indicator and the signals fed to a coupling device, if used, will correspond to the standard ILS throughout any manoeuvres necessary in the transition from the approach to the localizer to establishment on course line.

2.1.10.5 It should be realized, however, that for an increased runway length, the localizer course sector wherein proportional guidance is provided will be narrower as a result of adjusting the localizer to the sensitivity specified in Chapter 3, 3.1.3.7.1. Although a proportional guidance signal is provided on each side of the course line up to a level of 0.180 DDM, the level above 0.150 DDM may not be usable by the automatic airborne system during the intercept manoeuvre unless that system is armed within the sector in which a minimum of 0.180 DDM is provided (e.g. plus or minus 10 degrees). It is advantageous to permit the localizer capture mode of the automatic airborne system to be armed at off-course angles greater than 10 degrees; consequently it is desirable to maintain a minimum DDM of 0.180 through a wider sector than plus or minus 10 degrees wherever practical.

2.1.10.6 *Further possibilities.* If the disadvantages arising from the use of the restricted coverage and modified signal characteristics discussed in 2.1.10.3 are unacceptable, possibilities exist through the use of two radio frequency carriers to provide the coverage and signal characteristics that would maintain the essential information provided by a standard ILS in the suppressed sector while, at the same time, maintaining in the regions about the course sector the objective of the restricted coverage system. It may be necessary to employ this more elaborate system at aerodromes with high multipath environments. Additional guidance on two radio frequency carrier coverage is provided in 2.7.

2.2 ILS airborne receiving equipment

2.2.1 To ensure that the required operational objectives are achieved, it is necessary for the airborne receiving equipment to meet defined performance standards.

Note.— The relevant minimum operational performance standards for ILS receivers are detailed in RTCA DO-195 (1986) and EUROCAE ED-46B (including Amendments Nos. 1 and 2) for the localizer, in RTCA DO-143 (1970) and EUROCAE 1/WG 7/70 for the marker beacon, and in RTCA DO-192 (1986) and EUROCAE ED-47B (including Amendment No. 1) for the glide path receivers.

2.2.2 *Immunity performance of ILS localizer receiving systems to interference from VHF FM broadcast signals*

2.2.2.1 With reference to Note 2 of 3.1.4.2, Chapter 3, the immunity performance defined there must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Tests have shown that FM interference signals may affect both course guidance and flag current, and their effects vary depending on the DDM of the wanted signal which is applied. Additional information can be found in ITU Recommendation ITU-R SM.1140, *Test procedures for measuring receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–118 MHz.*

Note.— ITU Recommendation ITU-R SM.1140 can be found in the Manual on Testing of Radio Navigation Aids *(Doc* 8071*), Volume I.*

2.2.2.2 Commonly agreed methodology and formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3, 3.1.4. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R SM.1009-1, *Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–137 MHz.*

Note.— ITU Recommendation ITU-R SM.1009-1 can be found in Doc 8071, Volume I.

2.2.3 *Localizer and glide path antenna polarization*

2.2.3.1 Over the localizer and glide path frequency bands, respectively, the reception of vertically polarized signals from the forward direction with respect to the localizer and glide path antenna should be at least 10 dB below the reception of horizontally polarized signals from the same direction.

2.3 Alarm conditions for ILS airborne equipment

2.3.1 Ideally, a receiver alarm system such as a visual flag should warn a pilot of any unacceptable malfunctioning conditions which might arise within either the ground or airborne equipments. The extent to which such an ideal may be satisfied is specified below.

2.3.2 The alarm system is actuated by the sum of two modulation depths and, therefore, the removal of the ILS course modulation components from the radiated carrier should result in the actuation of the alarm.

2.3.3 The alarm system should indicate to the pilot and to any other airborne system which may be utilizing the localizer and glide path data, the existence of any of the following conditions:

a) the absence of any RF signal as well as the absence of simultaneous 90 Hz and 150 Hz modulation;

b) the percentage modulation of either the 90 Hz or 150 Hz signal reduction to zero with the other maintained at its normal 20 per cent and 40 per cent modulation respectively for the localizer and glide path;

Note.— It is expected that the localizer alarm occur when either the 90 Hz or 150 Hz modulation is reduced to 10 per cent with the other maintained at its normal 20 per cent. It is expected that the glide path alarm occur when either the 90 Hz or 150 Hz modulation is reduced to 20 per cent with the other maintained at its normal 40 per cent.

2.3.3.1 The alarm indication should be easily discernible and visible under all normal flight deck conditions. If a flag is used, it should be as large as practicable commensurate with the display.

2.4 Guidance for the siting, elevation, adjustment and coverage of glide path equipment

2.4.1 *Lateral placement.* The lateral placement of the glide path antenna system with respect to the runway centre line is normally not less than 120 m (400 ft). In deciding the lateral placement of the glide path antenna, account should be taken of the appropriate provisions of Annex 14 with regard to obstacle clearance surfaces and objects on strips for runways.

2.4.2 *ILS glide path curvature.* In many cases, the ILS glide path is formed as a conic surface originating at the glide path aerial system. Owing to the lateral placement of the origin of this conic surface from the runway centre line, the locus of the glide path in the vertical plane along the runway centre line is a hyperbola. Curvature of the glide path occurs in the threshold region and progressively increases until touchdown. To limit the amount of curvature, the glide path antenna should not be located at an excessive lateral distance from the runway centre line.

2.4.3 *Procedure design.* Chapter 3, 3.1.5.1 provides Standards and Recommended Practices for the glide path angle and the height of the ILS reference datum. The longitudinal position of the glide path antenna with respect to the runway threshold is established in order to provide the selected glide path angle and desired ILS reference datum height for the precision approach procedure designed for that runway. The precision approach procedure design may be modified to meet obstacle clearance requirements or to account for technical siting constraints for the glide path antenna (for example, crossing runways or taxiways). The procedure designer will take into account the acceptable glide path angle, threshold crossing height and runway length available as they relate to the type of aircraft expected to use the precision approach procedure.

2.4.4 *Longitudinal placement.* Assuming that the reflecting surface in the beam forming area can be approximated by a planar surface with appropriate lateral and longitudinal slopes, the required longitudinal position of the glide path antenna is then a function of the ILS reference datum above the runway threshold and of the projection of the glide path reflection plane along the runway centre line . This situation is described pictorially in Figure C-5. In this figure, the line OP is defined by the intersection between the glide path reflection plane and the vertical plane along the runway centre line, and point O is at the same longitudinal distance from the threshold as the glide path antenna. Depending on the height and orientation of the reflection plane, point O may be above or below the runway surface.

For a planar reflecting surface, the longitudinal position of the glide path antenna is then calculated as follows:

$$D = \frac{H + Y}{\tan(\theta) + \tan(\alpha)}$$

where

D = the horizontal distance between O and P (equivalent to the longitudinal distance from the glide path antenna to the runway threshold);

H = the nominal height of the ILS reference datum above the runway threshold;

Y = the vertical height of the runway threshold above P';

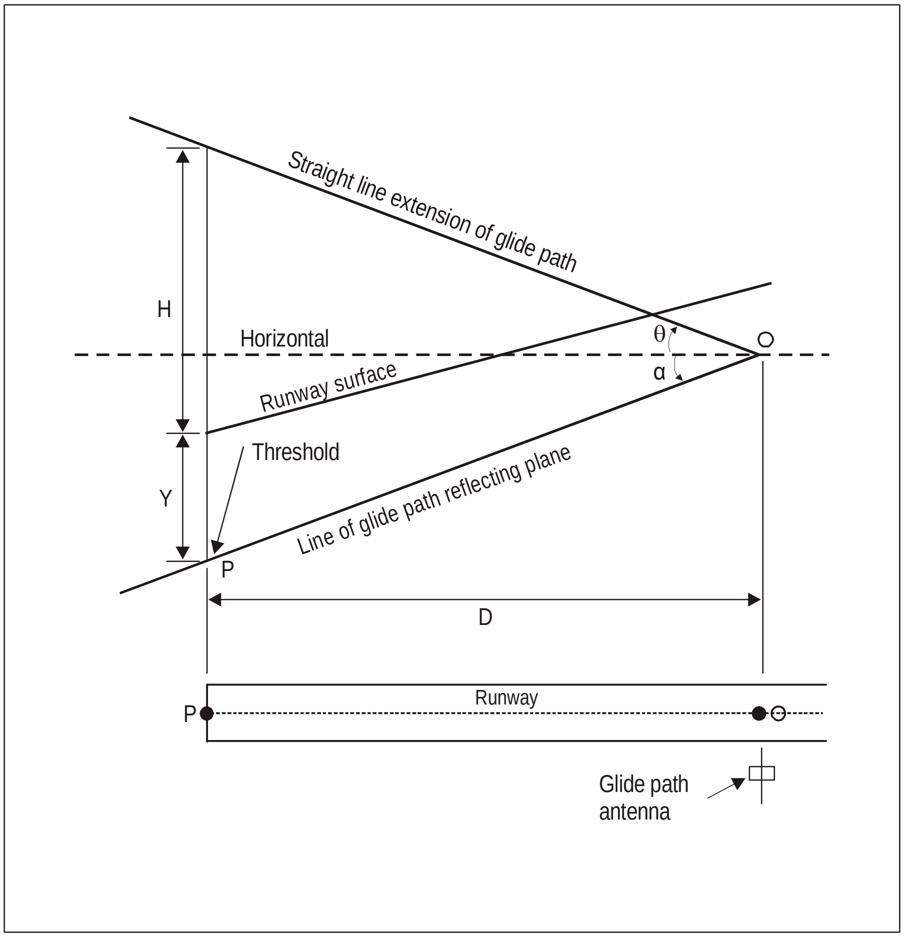


Figure C-5. Glide path siting for sloping runway

θ = the nominal ILS glide path angle;

α = the longitudinal downslope of the glide path reflection plane.

Note.— In the above formula α *is to be taken as positive in the case of a downslope from the antenna towards the threshold.* Y *is taken as positive if the threshold is above the reflection plane intersection line.*

2.4.5 The foregoing guidance material is based on the approximation of the reflecting surface by an appropriately oriented plane. Actual siting characteristics, such as significant lateral slope or an irregular rather than planar reflection surface, may require a more rigorous approach if the design goal for the height of the ILS reference datum is to be closely met. In challenging cases, mathematical modelling predictions of the effects of the siting conditions may be appropriate.

2.4.6 Typically, the glide path has some irregularities. The mean ILS glide path angle can be ascertained only by flight tests; the mean observed position of that part of the glide path between ILS Points A and B being represented as a straight line, and the ILS glide path angle being the angle measured between that straight line and its vertical projection on the horizontal plane.

2.4.7 It is important to recognize that the effect of glide path irregularities if averaged within the region between the middle marker and the threshold will likely tend to project a reference datum which is actually different from the ILS reference datum. This reference datum, defined here as the achieved ILS reference datum, is considered to be of important operational significance. The achieved ILS reference datum can only be ascertained by flight check, i.e. the mean observed position of that portion of the glide path typically between points 1 830 m (6 000 ft) and 300 m (1 000 ft) from the threshold being represented as a straight line and extended to touchdown. The point at which this extended straight line meets the line drawn vertically through the threshold at the runway centre line is the achieved ILS reference datum.

Note.— Further guidance on the measurement of the glide path angle and the achieved ILS reference datum is given in Doc 8071.

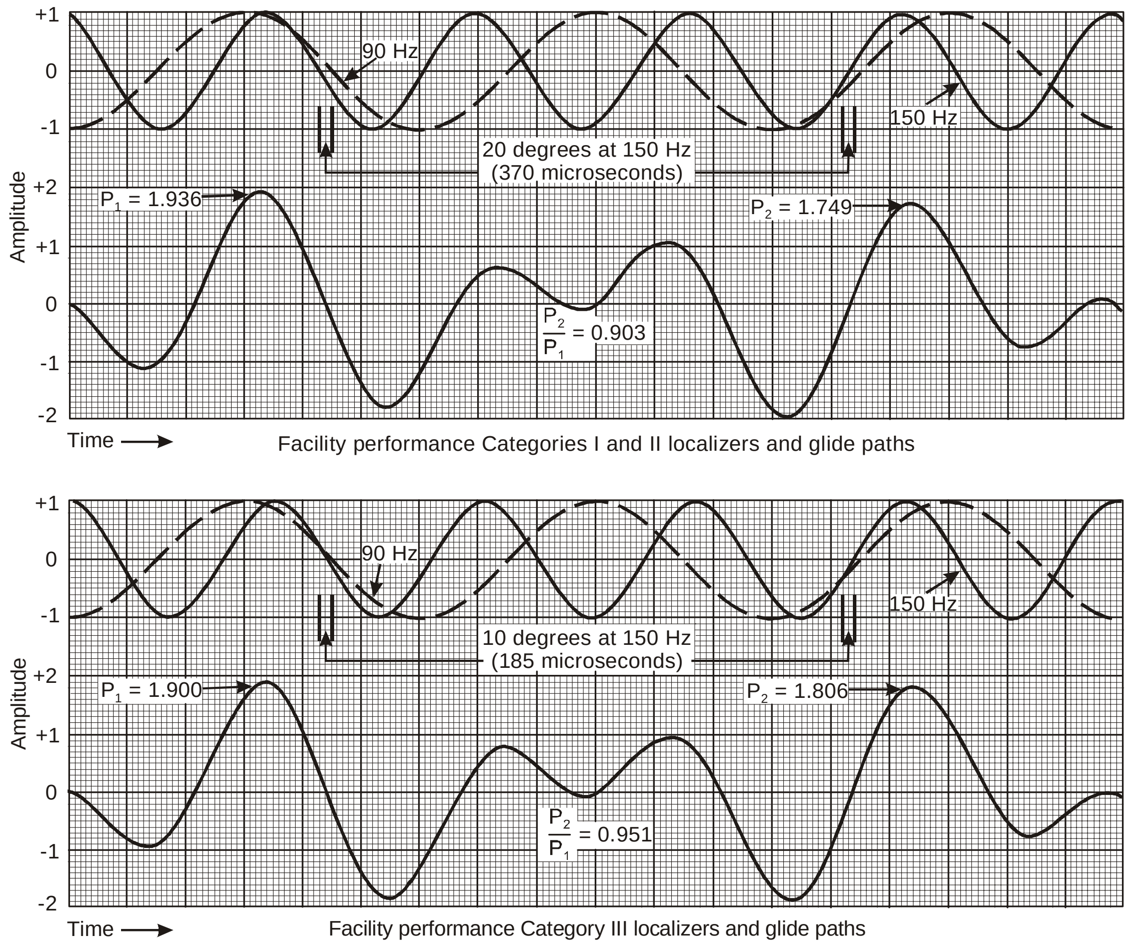
2.4.8 To reduce multipath interference to Category III glide paths and to reduce siting requirements and sensitive areas at these sites, it is desirable that the signals forming the horizontal radiation pattern from the Category III — ILS glide path antenna system be reduced to as low a value as practicable outside the azimuth coverage limits specified in Chapter 3, 3.1.5.3. Another acceptable method is to rotate in azimuth the glide path antennas away from multipath sources thus reducing the amount of radiated signals at specific angles while still maintaining the azimuth coverage limits.

2.4.9 Chapter 3, 3.1.5.3.1 indicates the glide path coverage to be provided to allow satisfactory operation of a typical aircraft installation. The operational procedures promulgated for a facility must be compatible with the lower limit of this coverage. It is usual for descents to be made to the intercept altitude and for the approach to continue at this altitude until a fly-down signal is received. In certain circumstances a cross-check of position may not be available at this point. Automatic flight control systems will normally start the descent whenever a fly-up signal has decreased to less than about 10 microamperes.

2.4.10 The objective is, therefore, to provide a fly-up signal prior to intercepting the glide path. Although under normal conditions, approach procedures will be accomplished in such a way that glide path signals will not be used below 0.45 θ, or beyond 18.5 km (10 NM) from the runway, it is desirable that misleading guidance information should not be radiated in this area. Where procedures are such that the glide path guidance may be used below 0.45 θ, adequate precautions must be taken to guard against the radiation of misleading guidance information below 0.45 θ, under both normal conditions and during a malfunction, thus preventing the final descent being initiated at an incorrect point on the approach. Some precautions which can be employed to guard against the radiation of misleading guidance include the radiation of a supplementary clearance signal such as provided for in Chapter 3, 3.1.5.2.1, the provision of a separate clearance monitor and appropriate ground inspection and setting-up procedures.

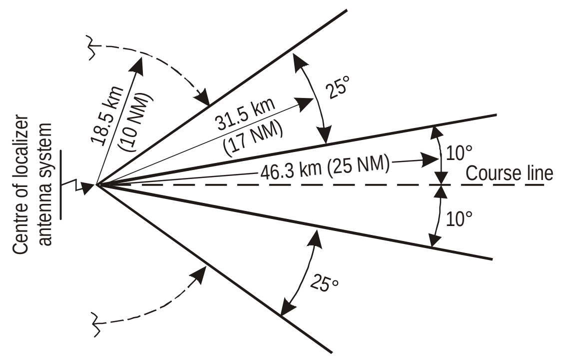
2.4.11 To achieve satisfactory monitor protection against below-path out-of-tolerance DDM, depending on the antenna system used, the displacement sensitivity monitor as required in Chapter 3, 3.1.5.7.1 e) may not be adequate to serve also as a clearance monitor. In some systems, e.g. those using multi-element arrays without supplementary clearance, a slight deterioration of certain antenna signals can cause serious degradation of the clearance with no change or only insignificant changes within the glide path sector as seen by the deviation sensitivity monitor. It is important to ensure that monitor alarm is achieved for any or all possible deteriorated antenna and radiated signal conditions, which may lead to a reduction of clearance to 0.175 DDM or less in the below-path clearance coverage.

2.5 Diagrams (Figures C-6 to C-12 illustrate certain of the Standards contained in Chapter 3)

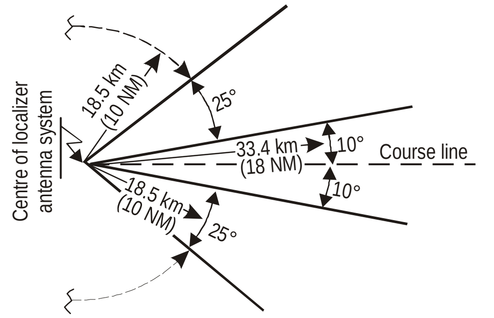


The accompanying graphs illustrate a method that can be used to measure the relative phase relationship between the 90 Hz and 150 Hz tones. The upper portion of each graph shows the individual waveforms and their relationship at the limit of phase differences allowed by Chapter 3, 3.1.3.5.3.3 and 3.1.5.5.3. The lower portion shows the combined waveforms as would be seen on an oscilloscope. By taking the ratio of P_1 and P_2, which gives a value equal to or less than unity, it is possible to determine if the phasing is within tolerance. For Categories I and II ILS the ratio should be greater than 0.903 and for Category III the ratio should be greater than 0.951.

Figure C-6. ILS wave forms illustrating relative audio phasing of the 90 Hz and 150 Hz tones

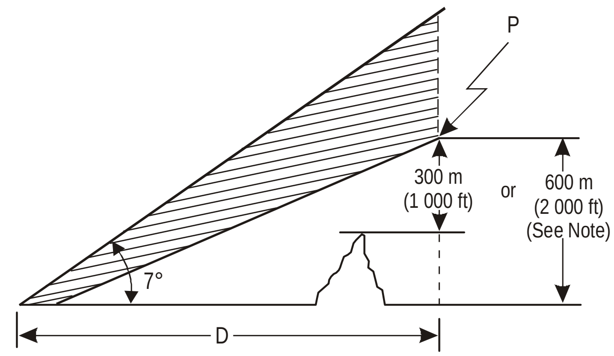


When topographical features dictate or operational requirements and alternative navigation facilities permit, the following coverage may be provided:



Note.— If coverage as prescribed in Chapter 3, 3.1.3.3.1 is required outside the plus or minus 35-degree sector, this is provided to 18.5 km (10 NM), as indicated by the broken arc above.

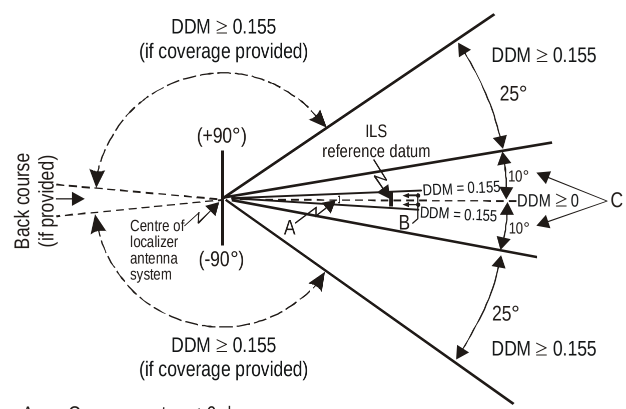
Figure C-7. Localizer coverage with respect to azimuth



D = Distances and azimuths specified in 3.1.3.3.1

Note.— The point P is either 600 metres (2 000 ft) above the elevation of the threshold, or 300 metres (1 000 ft) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher.

Figure C-8. Localizer coverage with respect to elevation



A — Course sector ≤ 6 degrees
B — Displacement sensitivity = 0.00145 DDM/metre (0.00044 DDM/foot) at the ILS reference datum
C — DDM increases linearly from zero to value of 0.180, and then ≥ 0.180

Figure C-9. Difference in depth of modulation and displacement sensitivity

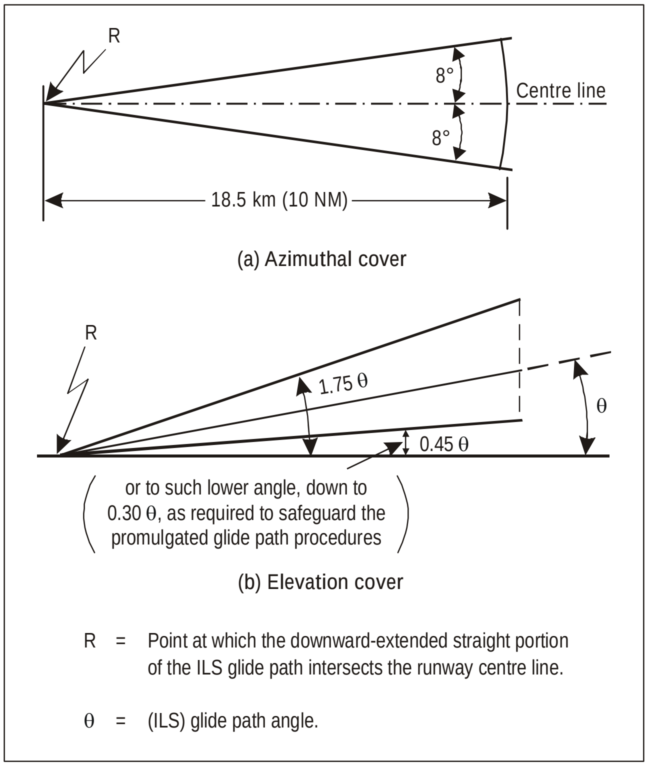


Figure C-10. Glide path coverage

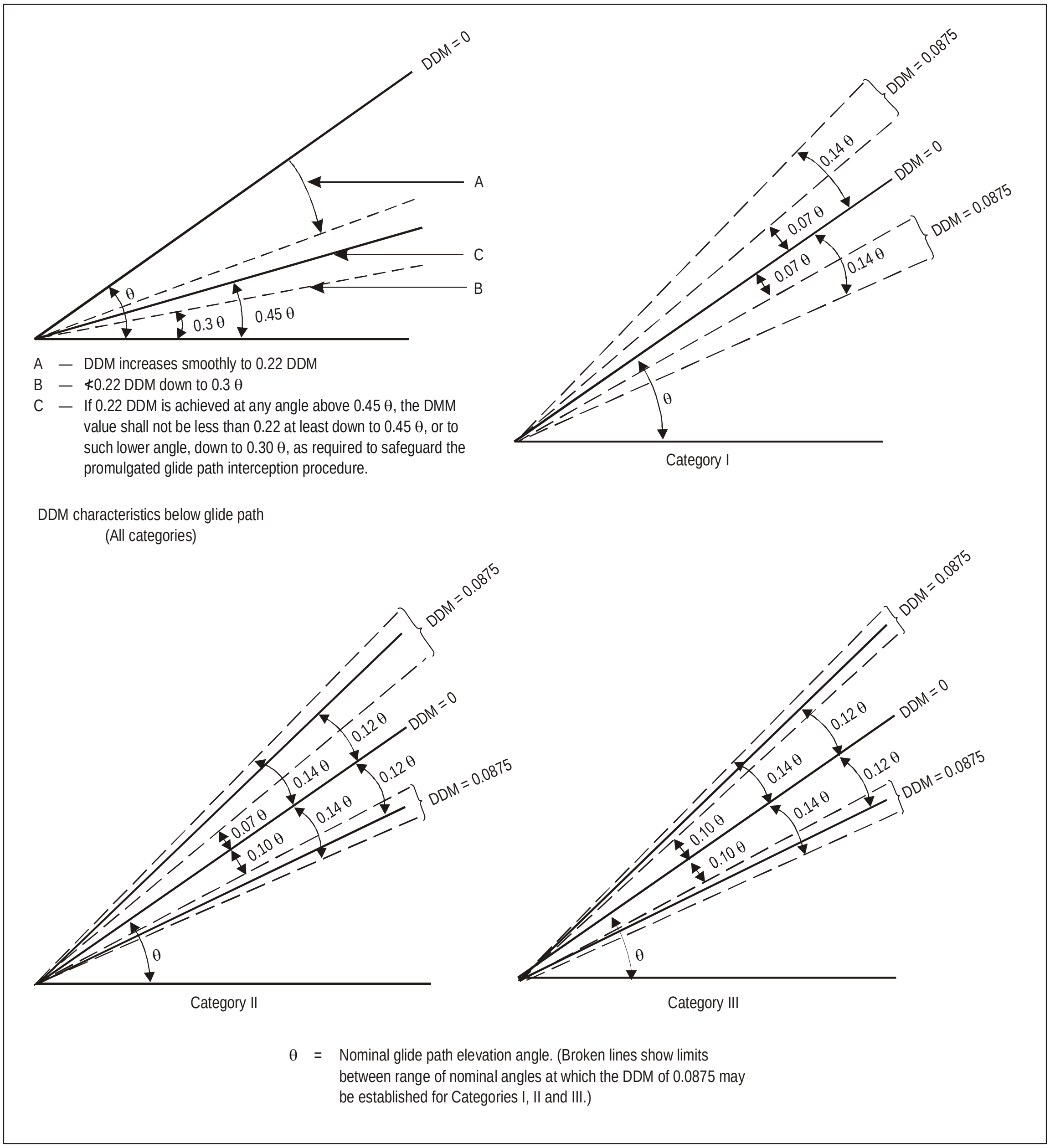
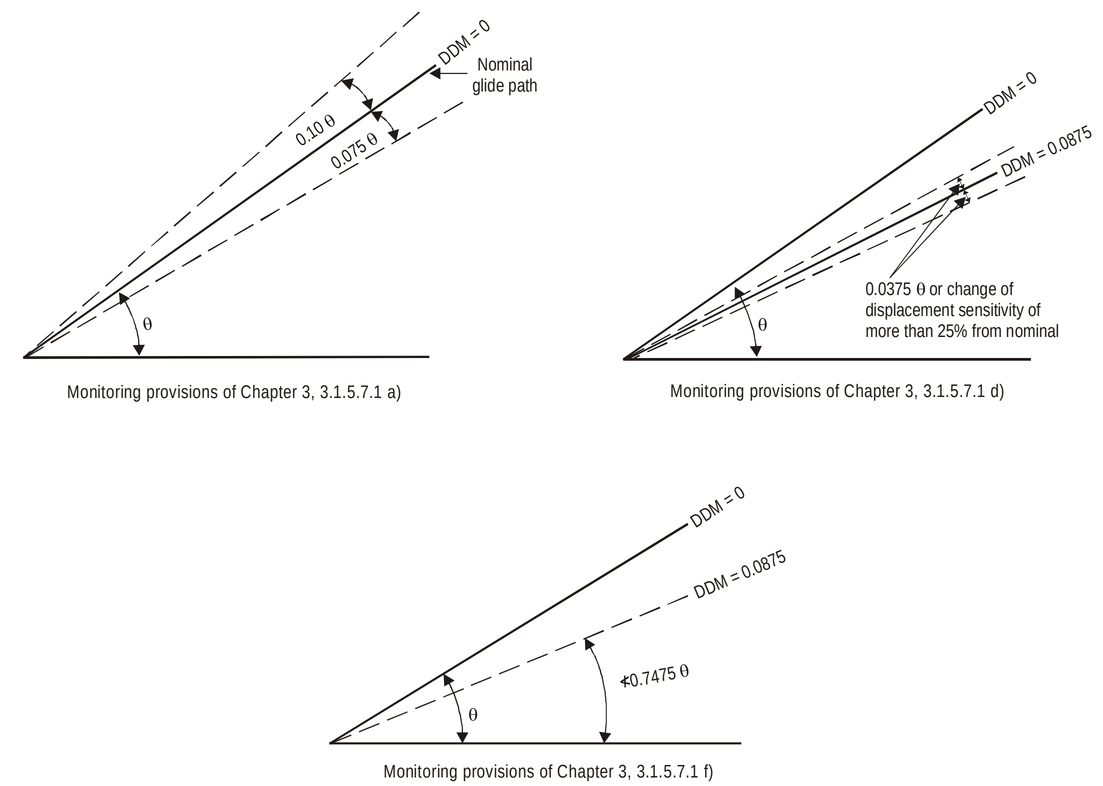


Figure C-11. Glide path — difference in depth of modulation



Note.— The broken lines represent the permissible limits of deviation before monitoring action is required.

Figure C-12. Glide path monitoring provisions

2.6 Deployment of ILS frequencies

2.6.1 In using the figures listed in Table C-1, it must be noted that these are related to ensuring freedom from interference to a point at the protection height and at the limit of service distance of the ILS in the direction of the front beam. If there is an operational requirement for back beam use, the criteria would also be applied to a similar point in the back beam direction. Frequency planning will therefore need to take into account the localizer azimuthal alignment. It is to be noted that the criteria must be applied in respect of each localizer installation, in the sense that while of two localizers, the first may not cause interference to the use of the second, nevertheless the second may cause interference to the use of the first.

2.6.2 The figures listed in Table C-1 are based on providing an environment within which the airborne receivers can operate correctly.

2.6.2.1 *ILS localizer receivers*

2.6.2.1.1 In order to protect receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

2.6.2.1.2 In order to protect receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

2.6.2.2 *ILS glide path receivers*

2.6.2.2.1 In order to protect receivers designed for 150 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

c) an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

Table C-1. Required distance separations

	Frequency separation	Minimum separation between second facility and the protection point of the first facility km (NM)		
		List A	List B	List C
Localizer	Co-channel	148 (80)	148 (80)	148 (80)
	50 kHz	—	37 (20)	9 (5)
	100 kHz	65 (35)	9 (5)	0
	150 kHz	—	0	0
	200 kHz	11 (6)	0	0
Glide path	Co-channel	93 (50)	93 (50)	93 (50)
	150 kHz	—	20 (11)	2 (1)
	300 kHz	46 (25)	2 (1)	0
	450 kHz	—	0	0
	600 kHz	9 (5)	0	0

List A refers to the use of localizer receivers designed for 200 kHz channel spacing coupled with glide path receivers designed for 600 kHz channel spacing and applicable only in regions where the density of facilities is low.

List B refers to the use of localizer receivers designed for 100 kHz channel spacing coupled with glide path receivers designed for 300 kHz channel spacing.

List C refers to the use of localizer receivers designed for 50 kHz channel spacing coupled with glide path receivers designed for 150 kHz channel spacing.

Note 1.— The above figures are based on the assumption of protection points for the localizer at 46 km (25 NM) distance and 1 900 m (6 250 ft) height and for the ILS glide path at 18.5 km (10 NM) distance and 760 m (2 500 ft) height.

Note 2.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS and VOR facilities in a manner which will preclude the possibility of airborne receiver error due to overloading by high unwanted signal levels when the aircraft is in the initial and final approach phases.

Note 3.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS glide path facilities in a manner which will preclude the possibility of erroneous glide path indications due to reception of adjacent channel signals when the desired signal ceases to radiate for any reason while the aircraft is in the final approach phase.

2.6.2.2.2 In order to protect receivers designed for 300 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, does not exceed the desired signal (0 dB signal ratio);

c) an undesired glide path signal, 300 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

d) an undesired glide path signal, 450 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

2.6.3 The calculations are based on the assumption that the protection afforded to the wanted signal against interference from the unwanted signal is 20 dB. This corresponds to a disturbance of not more than 15 microamperes at the limit of the service distance of ILS.

2.6.4 In so far as the wanted and unwanted carriers may produce a heterodyne note, the protection ratio ensures that the instrumentation is not affected. However, in cases where a voice facility is used, the heterodyne note may interfere with this facility.

2.6.5 In general, when international use of ILS systems is confined to the pairings listed in Chapter 3, 3.1.6.1.1, the criteria are such that, provided they are met for the localizer element, the glide path element is automatically covered. At certain congested locations, where it is necessary to make assignments in both the first ten and the second ten sequence pairings, it may be necessary to select certain pairings out of sequence in order to meet the minimum geographical separation in 2.6.6.

Example: Referring to Chapter 3, 3.1.6.1.1, it will be noted that ILS Sequence Number 2 pairs the localizer frequency of 109.9 MHz with glide path frequency 333.8 MHz. Sequence Numbers 12 and 19, however, although providing wide frequency separation from Sequence Number 2 in the case of the localizers, assign frequencies of 334.1 MHz and 333.5 MHz, respectively, for the glide paths, both being first adjacent channels (300 kHz spacing) to the Sequence Number 2 glide path channel. If selection of ILS channels is confined to either the first ten or the second ten pairings, then the minimum glide path frequency separation will be 600 kHz.

2.6.6 *Table of required distance separations* (see Table C-1)

2.6.7 The application of the figures given in Table C-1 will only be correct within the limitations set by the assumptions which include that facilities are essentially non-directional in character, that they have similar radiated powers, that the field strength is approximately proportional to the angle of elevation for angles up to 10 degrees, and that the aircraft antenna is essentially omnidirectional in character. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves, taking into account the particular directivity factors, radiated power characteristics and the operational requirements as to coverage. Where reduced separation distances are determined by taking into account directivity, etc., flight measurements at the ILS protection point and at all points on the approach path should be made wherever possible to ensure that a protection ratio of at least 20 dB is achieved in practice.

2.7 Localizers and glide paths achieving coverage with two radio frequency carriers

2.7.1 Localizer and glide path facilities may achieve their coverage requirements by using two radiation field patterns, commonly known as the “course” and “clearance” patterns, transmitted using separate carrier frequencies spaced within the frequency channel. The course field pattern gives accurate course and displacement indications; the clearance field pattern provides displacement indications at angles beyond the limits of the course field pattern . Discrimination between signals is obtained in airborne receivers by the stronger signal capturing the receiver. Effectiveness of capture depends on the type of detector used but, in general, if the ratio of the two signals is of the order of 10 dB or more, the smaller signal does not cause significantly large errors in demodulated output. For optimum performance within the front course sector, the following guidance material should be applied in the operation of two carrier frequency localizer systems.

2.7.2 The localizer should be designed and maintained so that the ratio of the two radiated signals-in-space within the front course sector does not fall below 10 dB. Particular attention should be directed to the vertical lobe structure produced by the two antenna systems which may be different in height and separated in distance, thus resulting in changes in ratio of signal strengths during approach.

2.7.3 Due to the 6 dB allowance for the receiver pass-band filter ripple, localizer receiver response variations can occur as the clearance frequency is displaced from the course frequency. To minimize this effect, particularly for Category III operations, the course-to-clearance signal ratio needs to be increased from 10 dB to 16 dB.

2.7.4 To minimize further the risk of errors if the ratio of the two radiated signals falls below 10 dB within the front course sector, the difference in alignment of the radiation field patterns of the two signals should be kept as minimal as practicable.

2.7.5 Glide paths which employ two carriers are used to form a composite radiation field pattern on the same radio frequency channel. Special configurations of antennas and the distribution of antenna currents and phasing may permit siting of glide path facilities at locations with particular terrain conditions which may otherwise cause difficulty to a single-frequency system. At such sites, an improvement is obtained by reducing the low angle radiation. The second carrier is employed to provide coverage in the region below the glide path.

2.7.6 *Monitoring dual frequency systems.* The dual frequency monitoring requirements in Chapter 3, 3.1.3.11.2 e) and 3.1.5.7.1 c) specify monitor action for a power output of less than 80 per cent of normal, except that reductions can be accepted to 50 per cent of normal if certain performance requirements are met.

2.7.6.1 Monitoring the course and clearance transmitters for a 20 per cent reduction in power (approximately –1 dB) can be challenging if environmental and other effects such as large ambient temperature variations exist at the site. For example, temperature variations cause normal transmitter power output to vary and coaxial cable insertion losses to change. Even assuming no failure occurs in the transmitting system, the alarm limit occasionally may be exceeded, and this in turn may compromise continuity.

2.7.6.2 The alternative of monitoring at power reductions of up to 50 per cent appears very attractive, but must be used cautiously. Monitoring each transmitter independently at a 50 per cent reduction can allow a large change from the nominal power ratio between the two transmitters if uncorrelated failures occur. This in turn may compromise the capture effect in the receiver, thus increasing structure errors or reducing clearance indications.

2.7.6.3 One solution is to use a monitoring scheme that limits the difference between the power output of the transmitters to approximately 1 dB (i.e. 80 per cent), while allowing both to decrease up to 3 dB (i.e. 50 per cent) if they change together. This method provides a greater tolerance for common mode effects such as cable loss changes due to temperature, and therefore increases continuity of service.

2.8 Integrity and continuity of service — ILS ground equipment

2.8.1 *Introduction*

2.8.1.1 This material is intended to provide clarification of the integrity and continuity of service objectives of ILS localizer and glide path ground equipment and to provide guidance on engineering design and system characteristics of this equipment. Integrity is needed to ensure that an aircraft on approach will have a low probability of receiving false guidance; continuity of service is needed to ensure that an aircraft in the final stages of approach will have a low probability of being deprived of a guidance signal. Integrity and continuity of service are both key safety factors during the critical phase of approach and landing. The integrity and continuity of service must of necessity be known from an operational viewpoint in order to decide the operational application which an ILS could support.

2.8.1.2 It is generally accepted, irrespective of the operational objective, that the average rate of a fatal accident during landing, due to failures or shortcomings in the whole system, comprising the ground equipment, the aircraft and the pilot, should not exceed 1×10^{-7}. This criterion is frequently referred to as the global risk factor.

2.8.1.3 In the case of Category I operations, responsibility for assuring that the above objective is not exceeded is vested more or less completely in the pilot. In Category III operations, the same objective is required but must now be inherent in the whole system. In this context it is of the utmost importance to endeavour to achieve the highest level of integrity and continuity of service of the ground equipment.

2.8.1.4 The requirements for integrity and high continuity of service require highly reliable systems to minimize the probability of failure which may affect any characteristic of the total signal-in-space. It is suggested that States endeavour to achieve reliability with as large a margin as is technically and economically reasonable. Reliability of equipment is governed by basic construction and operating environment. Equipment design should employ the most suitable engineering techniques, materials and components, and rigorous inspection should be applied in manufacture. Equipment should be operated in environmental conditions appropriate to the manufacturers' design criteria.

2.8.2 *Achievement and retention of integrity service levels*

2.8.2.1 An integrity failure can occur if radiation of a signal which is outside specified tolerances is either unrecognized by the monitoring equipment or the control circuits fail to remove the faulty signal. Such a failure might constitute a hazard if it results in a gross error.

2.8.2.2 Clearly not all integrity failures are hazardous in all phases of the approach. For example, during the critical stages of the approach, undetected failures producing gross errors in course width or course line shifts are of special significance whereas an undetected change of modulation depth, or loss of localizer and glide slope clearance and localizer identification would not necessarily produce a hazardous situation. The criterion in assessing which failure modes are relevant must however include all those deleterious fault conditions which are not unquestionably obvious to the automatic flight system or pilot.

2.8.2.3 The highest order of protection is required against the risk of undetected failures in the monitoring and associated control system. This would be achieved by careful design to reduce the probability of such occurrences to a low level and provide fail-safe operations compliant with the Standards of Chapter 3, 3.1.3.11.4 and 3.1.5.7.4, and by carrying out maintenance checks on the monitor system performance at intervals which are determined by a design analysis.

2.8.2.4 A design analysis can be used to calculate the level of integrity of the system in any one landing. The following formula applies to certain types of ILS and provides an example of the determination of system integrity, *I*, from a calculation of the probability of transmission of undetected erroneous radiation, *P*.

(1) $I = 1 - P$

$$P = \frac{T_1 T_2}{\alpha_1 \alpha_2 M_1 M_2} \text{ when } T_1 < T_2$$

where

I = integrity

P = the probability of a concurrent failure in transmitter and monitor systems resulting in erroneous undetected radiation

M_1 = transmitter mean time between failures (MTBF)

M_2 = MTBF of the monitoring and associated control system

$\frac{1}{\alpha_1}$ = ratio of the rate of failure in the transmitter resulting in the radiation of an erroneous signal to the rate of all transmitter failures

$\frac{1}{\alpha_2}$ = ratio of the rate of failure in the monitoring and associated control system resulting in inability to detect an erroneous signal to the rate of all monitoring and associated control system failures

T_1 = period of time (in hours) between transmitter checks

T_2 = period of time (in hours) between checks on the monitoring and associated control system

When $T_1 \geq T_2$ the monitor system check may also be considered a transmitter check. In this case, therefore $T_1 = T_2$ and the formula would be:

(2) $$P = \frac{T_2^2}{\alpha_1 \alpha_2 M_1 M_2}$$

2.8.2.5 Since the probability of occurrence of an unsafe failure within the monitoring or control equipment is extremely remote, to establish the required integrity level with a high degree of confidence would necessitate an evaluation period many times that needed to establish the equipment MTBF. Such a protracted period is unacceptable and therefore the required integrity level can only be predicted by rigorous design analysis of the equipment.

2.8.2.6 Protection of the integrity of the signal-in-space against degradation which can arise from extraneous radio interference falling within the ILS frequency band or from re-radiation of ILS signals must also be considered. Measures to prevent the latter by critical and sensitive area protection are given in general terms at 2.1.9. With regard to radio interference it may be necessary to confirm periodically that the level of interference does not constitute a hazard.

2.8.2.7 In general, monitoring equipment design is based on the principle of continuously monitoring the radiated signals-in-space at specific points within the coverage volume to ensure their compliance with the Standards specified at Chapter 3, 3.1.3.11 and 3.1.5.7. Although such monitoring provides to some extent an indication that the signal-in-space at all other points in the coverage volume is similarly within tolerance, this is largely inferred. It is essential therefore to carry out rigorous flight and ground inspections at periodic intervals to ensure the integrity of the signal-in-space throughout the coverage volume.

2.8.3 *Achievement and retention of continuity of service levels*

2.8.3.1 A design analysis should be used to predict the MTBF and continuity of service of the ILS equipment. Before assignment of a level of continuity of service and introduction into Category II or III service, however, the mean time between outages (MTBO) of the ILS should be confirmed by evaluation in an operational environment. In this evaluation, an outage is defined as any unanticipated cessation of signal-in-space. This evaluation takes into account the impact of operational factors, i.e. airport environment, inclement weather conditions, power availability, quality and frequency of maintenance. MTBO is related to MTBF, but is not equivalent, as some equipment failures, such as a failure of a transmitter resulting in the immediate transfer to a standby transmitter may not necessarily result in an outage. For continuity of service Level 2, 3 or 4, the evaluation period should be sufficient to determine achievement of the required level with a high degree of confidence. One method to demonstrate that continuity standards are met is the sequential test method. If this method is used, the following considerations apply:

a) the minimum acceptable confidence level is 60 per cent. To achieve the confidence level of 60 per cent, the evaluation period has to be longer than the required MTBO hours as stated in Table C-2. Typically, these minimal evaluation periods for new and subsequent installations are for Level 2, 1 600 operating hours, for Level 3, 3 200 hours and for Level 4, 6 400 hours. To assess the seasonal influence of the environment, a minimal evaluation period of one year is typically required for a new type of installation in a particular environment. It may be possible to reduce this period in cases where the operating environment is well controlled and similar to other proven installations. Where several identical systems are being operated under similar conditions, it may be possible to base the assessment on the cumulative operating hours of all the systems; this will result in a reduced evaluation period. Once a higher confidence level is obtained for a type of installation, subsequent installation of the same type of equipment under similar operational and environmental conditions may follow shorter evaluation periods;

b) during the evaluation period, it should be decided for each outage if it is caused by a design failure or if it is caused by a failure of a component due to its normal failure rate. Design failures are, for instance, operating components beyond their specification (overheating, overcurrent, overvoltage, etc. conditions). These design failures should be dealt with such that the operating condition is brought back to the normal operating condition of the component or that the component is replaced with a part suitable for the operating conditions. If the design failure is treated in this way, the evaluation may continue and this outage is not counted, assuming that there is a high probability that this design failure will not occur again. The same applies to outages due to any causes which can be mitigated by permanent changes to the operating conditions.

2.8.3.2 An assigned continuity of service level should not be subject to frequent change. A suitable method to assess the behaviour of a particular installation is to keep the records and calculate the average MTBO over the last five to eight failures of the equipment. This weighs the MTBO for continuity of service purposes to be more relevant to the next approach, rather than computing MTBO over the lifetime of the equipment. If continuity of service deteriorates, the assigned designation should be reduced until improvements in performance can be effected.

2.8.3.3 *Additional detailed guidance.* Several States have published continuity of service policies and procedures. The following documents may be consulted for additional guidance and details:

a) *European Guidance Material on Continuity of Service Evaluation in Support of the Certification of ILS & MLS Ground Systems*, EUR DOC 012; and

b) *Instrument Landing System Continuity of Service Requirements and Procedures*, Order 6750.57, United States Federal Aviation Administration.

2.8.4 The following configuration is an example of a redundant equipment arrangement that is likely to meet the objectives for integrity and continuity of service Levels 3 and 4. The localizer and glide path facilities each consist of two continuously operating transmitters, one connected to the antenna and the standby connected to a dummy load. With these transmitters is associated a monitor system performing the following functions:

a) confirming proper operation within the specified limits of the main transmitter and antenna system by means of majority voting among redundant monitors;

b) confirming operation of the standby equipment.

2.8.4.1 Whenever the monitor system rejects one of the equipments the facility continuity of service level will be reduced because the probability of cessation of signal consequent on failure of other equipment will be increased. This change of performance must be automatically indicated at remote locations.

2.8.4.2 An identical monitoring arrangement to the localizer is used for the glide path facility.

2.8.4.3 To reduce mutual interference between the main and standby transmitters any stray radiation from the latter is at least 50 dB below the carrier level of the main transmitter measured at the antenna system.

2.8.4.4 In the above example, the equipment would include provision to facilitate monitoring system checks at intervals specified by the manufacturer, consequent to the design analysis, to ensure attainment of the required integrity level. Such checks, which can be manual or automatic, provide the means to verify correct operation of the monitoring system including the control circuitry and changeover switching system. The advantage of adopting an automatic monitor integrity test is that no interruption to the operational service provided by the localizer or glide path is necessary. It is important when using this technique to ensure that the total duration of the check cycle is short enough not to exceed the total period specified in Chapter 3, 3.1.3.11.3 or 3.1.5.7.3.

2.8.4.5 Interruption of facility operation due to primary power failures is avoided by the provision of suitable standby supplies, such as batteries or “no-break” generators. Under these conditions, the facility should be capable of continuing in operation over the period when an aircraft may be in the critical stages of the approach. Therefore the standby supply should have adequate capacity to sustain service for at least two minutes.

2.8.4.6 Warnings of failures of critical parts of the system, such as the failure of the primary power supply, must be given at the designated control points.

2.8.4.7 In order to reduce failure of equipment that may be operating near its monitor tolerance limits, it is useful for the monitor system to include provision to generate a pre-alarm warning signal to the designated control point when the monitored parameters reach a limit equal to a value in the order of 75 per cent of the monitor alarm limit.

2.8.4.8 An equipment arrangement similar to that at 2.8.4, but with no transmitter redundancy, would normally be expected to achieve the objectives for continuity of service Level 2.

2.8.5 Guidance relating to localizer far field monitors is given below.

2.8.5.1 Far field monitors are provided to monitor course alignment but may also be used to monitor course sensitivity. A far field monitor operates independently from integral and near field monitors. Its primary purpose is to protect against the risk of erroneous setting-up of the localizer, or faults in the near field or integral monitors. In addition, the far field monitor system will enhance the ability of the combined monitor system to respond to the effects of physical modification of the radiating elements or variations in the ground reflection characteristics. Moreover, multipath effects and runway area disturbances not seen by near field and integral monitors, and some occurrences of radio interferences may be substantially monitored by using a far field monitoring system built around a suitable receiver(s), installed under the approach path.

2.8.5.2 A far field monitor is generally considered essential for Category III operations, while for Category II it is generally considered to be desirable. Also for Category I installations, a far field monitor has proved to be a valuable tool to supplement the conventional monitor system.

2.8.5.3 The signal received by the far field monitor will suffer short-term interference effects caused by aircraft movements on or in the vicinity of the runway and experience has shown that it is not practical to use the far field monitor as an executive monitor. When used as a passive monitor, means must be adopted to minimize such temporary interference effects and to reduce the occurrence of nuisance downgrade indications; some methods of achieving this are covered in 2.8.5.4. The response of the far field monitor to interference effects offers the possibility of indicating to the air traffic control point when temporary disturbance of the localizer signal is present. However, experience has shown that disturbances due to aircraft movements may be present along the runway, including the touchdown zone, and not always be observed at the far field monitor. It must not be assumed, therefore, that a far field monitor can provide comprehensive surveillance of aircraft movements on the runway.

2.8.5.3.1 Additional possible applications of the far field monitor are as follows:

a) it can be a useful maintenance aid to verify course and/or course deviation sensitivity in lieu of a portable far field monitor;

b) it may be used to provide a continuous recording of far field signal performance showing the quality of the far field signal and the extent of signal disturbance.

2.8.5.4 Possible methods of reducing the occurrence of nuisance downgrade indications include:

a) incorporation of a time delay within the system adjustable from 30 to 240 seconds;

b) the use of a validation technique to ensure that only indications not affected by transitory disturbances are transmitted to the control system;

c) use of low pass filtering.

2.8.5.5 A typical far field monitor consists of an antenna, VHF receiver and associated monitoring units which provide indications of DDM, modulation sum, and RF signal level. The receiving antenna is usually of a directional type to minimize unwanted interference and should be at the greatest height compatible with obstacle clearance limits. For course line monitoring, the antenna is usually positioned along the extended runway centre line. Where it is desired to also monitor displacement sensitivity, an additional receiver and monitor are installed with antenna suitably positioned to one side of the extended runway centre line. Some systems utilize a number of spatially separated antennas.

2.9 Localizer and glide path displacement sensitivities

2.9.1 Although certain localizer and glide path alignment and displacement sensitivities are specified in relation to the ILS reference datum, it is not intended to imply that measurement of these parameters must be made at this datum.

2.9.2 Localizer monitor system limits and adjustment and maintenance limits given in Chapter 3, 3.1.3.7 and 3.1.3.11 are stated as percentage changes of displacement sensitivity. This concept, which replaces specifications of angular width in earlier editions, has been introduced because the response of aircraft guidance systems is directly related to displacement sensitivity. It will be noted that angular width is inversely proportional to displacement sensitivity.

2.10 Siting of ILS markers

2.10.1 Considerations of interference between inner and middle markers, and the minimum operationally acceptable time interval between inner and middle marker light indications, will limit the maximum height marked by the inner marker to a height on the ILS glide path of the order of 37 m (120 ft) above threshold for markers sited within present tolerances in Annex 10. A study of the individual site will determine the maximum height which can be marked, noting that with a typical airborne marker receiver a separation period of the order of 3 seconds at an aircraft speed of 140 kt between middle and inner marker light indications is the minimum operationally acceptable time interval.

2.10.2 In the case of ILS installations serving closely spaced parallel runways, e.g. 500 m (1 650 ft) apart, special measures are needed to ensure satisfactory operation of the marker beacons. Some States have found it practical to employ a common outer marker for both ILS installations. However, special provisions, e.g. modified field patterns, are needed in the case of the middle markers if mutual interference is to be avoided, and especially in cases where the thresholds are displaced longitudinally from one another.

2.11 Use of DME as an alternative to ILS marker beacons

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

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

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

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

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

2.12 The use of supplementary sources of orientation guidance in association with ILS

2.12.1 Aircraft beginning an ILS approach may be assisted by guidance information provided by other ground referenced facilities such as VORs, surveillance radar or, where these facilities cannot be provided, by a locator beacon.

2.12.2 When not provided by existing terminal or en-route facilities, a VOR, suitably sited, will provide efficient transition to the ILS. To achieve this purpose the VOR may be sited on the localizer course or at a position some distance from the localizer course provided that a radial will intersect the localizer course at an angle which will allow smooth transitions in the case of auto coupling. The distance between the VOR site and the desired point of interception must be recognized when determining the accuracy of the interception and the airspace available to provide for tracking errors.

2.12.3 Where it is impracticable to provide a suitably sited VOR, a compass locator or an NDB can assist transition to the ILS. The facility should be sited on the localizer course at a suitable distance from the threshold to provide for optimum transition.

2.13 The use of Facility Performance Category I — ILS for automatic approaches and landings in visibility conditions permitting visual monitoring of the operation by the pilot

2.13.1 Facility Performance Category I — ILS installations of suitable quality can be used, in combination with aircraft flight control systems of types not relying solely on the guidance information derived from the ILS sensors, for automatic approaches and automatic landings in visibility conditions permitting visual monitoring of the operation by the pilot.

2.13.2 To assist aircraft operating agencies with the initial appraisal of the suitability of individual ILS installations for such operations, provider States are encouraged to promulgate:

a) the differences in any respect from Chapter 3, 3.1;

b) the extent of compliance with the provisions in Chapter 3, 3.1.3.4 and 3.1.5.4, regarding localizer and glide path beam structure; and

c) the height of the ILS reference datum above the threshold.

2.13.3 To avoid interference which might prevent the completion of an automatic approach and landing, it is necessary that local arrangements be made to protect, to the extent practicable, the ILS critical and sensitive areas.

2.14 ILS classification — supplementary ILS description method with objective to facilitate operational utilization

2.14.1 The classification system given below, in conjunction with the current facility performance categories, is intended to provide a more comprehensive method of describing an ILS.

2.14.2 The ILS classification is defined by using three characters as follows:

a) I, II or III: this character indicates conformance to Facility Performance Category in Chapter 3, 3.1.3 and 3.1.5.

b) A, B, C, T, D or E: this character defines the ILS points to which the localizer structure conforms to the course structure given at Chapter 3, 3.1.3.4.2, except the letter T, which designates the runway threshold. The points are defined in Chapter 3, 3.1.1.

c) 1, 2, 3 or 4: this number indicates the level of integrity and continuity of service given in Table C-2.

Note.— In relation to specific ILS operations it is intended that the level of integrity and continuity of service would typically be associated as follows:

1) Level 2 is the performance objective for ILS equipment used to support low visibility operations when ILS guidance for position information in the landing phase is supplemented by visual cues. This level is a recommended objective for equipment supporting Category I operations;

2) Level 3 is the performance objective for ILS equipment used to support operations which place a high degree of reliance on ILS guidance for positioning through touchdown. This level is a required objective for equipment supporting Category II and IIIA operations; and

3) Level 4 is the performance objective for ILS equipment used to support operations which place a high degree of reliance on ILS guidance throughout touchdown and rollout. This level basically relates to the needs of the full range of Category III operations.

2.14.3 As an example, a Facility Performance Category II — ILS which meets the localizer course structure criteria appropriate to a Facility Performance Category III — ILS down to ILS point "D" and conforms to the integrity and continuity of service objectives of Level 3 would be described as class II/D/3.

2.14.4 ILS classes are appropriate only to the ground ILS element. Consideration of operational categories must also include additional factors such as operator capability, critical and sensitive area protection, procedural criteria and ancillary aids, such as transmissometers and lights.

Table C-2. Integrity and continuity of service objectives

	Localizer or glide path		
Level	Integrity	Continuity of service	MTBO (hours)
1		Not demonstrated, or less than required for Level 2	
2	$1 - 10^{-7}$ in any one landing	$1 - 4 \times 10^{-6}$ in any period of 15 seconds	1 000
3	$1 - 0.5 \times 10^{-9}$ in any one landing	$1 - 2 \times 10^{-6}$ in any period of 15 seconds	2 000
4	$1 - 0.5 \times 10^{-9}$ in any one landing	$1 - 2 \times 10^{-6}$ in any period of 30 seconds (localizer) 15 seconds (glide path)	4 000 (localizer) 2 000 (glide path)

Note.— For currently installed systems, in the event that the Level 2 integrity value is not available or cannot be readily calculated, it is necessary to at least perform a detailed analysis of the integrity to assure proper monitor fail-safe operation.

2.15 ILS carrier frequency and phase modulation

2.15.1 In addition to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carriers, undesired frequency modulation (FM) and/or phase modulation (PM) may exist. This undesired modulation can cause centring errors in ILS receivers due to slope detection by ripple in the intermediate frequency (IF) filter pass-band.

2.15.2 For this to occur, the translated RF carrier frequency must fall on an IF frequency where the pass-band has a high slope. The slope converts the undesired 90 Hz and 150 Hz frequency changes to AM of the same frequencies. Similarly, any difference in FM deviation between the undesired 90 Hz and 150 Hz components is converted to DDM, which in turn produces an offset in the receiver. The mechanism is identical for PM as for FM, since PM causes a change in frequency equal to the change in phase (radians) multiplied by the modulating frequency.

2.15.3 The effect of the undesired FM and/or PM is summed by vector addition to the desired AM. The detected FM is either in phase or anti-phase with the AM according to whether the pass-band slope at the carrier's IF is positive or negative. The detected PM is in quadrature with the AM, and may also be positive or negative according to the pass-band slope.

2.15.4 Undesired FM and/or PM from frequencies other than 90 Hz and 150 Hz, but which pass through the 90 Hz and 150 Hz tone filters of the receiver, can also cause changes to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carrier, resulting in a DDM offset error in the receiver. Thus, it is essential that when measuring undesired FM and PM levels, audio band-pass filters with a pass-band at least as wide as that of the tone filters of ILS receivers be used. These filters are typically inserted in commercial modulation meter test equipment between the demodulation and metering circuits, to ensure that only spectral components of interest to ILS applications are measured. To standardize such measurements, the filter characteristics are recommended as shown below:

Frequency (Hz)	*90 Hz band-pass filter attenuation, dB*	*150 Hz band-pass filter attenuation, dB*
≤45	–10	–16
85	–0.5	(no specification)
90	0	–14
95	–0.5	(no specification)
142	(no specification)	–0.5
150	–14	0
158	(no specification)	–0.5
≥300	–16	–10

2.15.5 The preferred maximum limits, as shown below, are derived from ILS receiver centring error limits specified in EUROCAE documents ED-46B and ED-47B, based on the worst-case-to-date observed correlation between undesired modulation levels and centring errors:

Facility type	*90 Hz peak deviation, FM Hz/PM radians (Note 1)*	*150 Hz peak deviation, FM Hz/PM radians (Note 2)*	*Deviation difference, Hz (Note 3)*
Localizer, Cat I	135/1.5	135/0.9	45
Localizer, Cat II	60/0.66	60/0.4	20
Localizer, Cat III	45/0.5	45/0.3	15
Glide path, Cat I	150/1.66	150/1.0	50
Glide path, Cat II or III	90/1.0	90/0.6	30

Note 1.— This column applies to the peak frequency or phase deviation as measured with the 90 Hz tone filter specified in 2.15.4.

Note 2.— This column applies to the peak frequency or phase deviation as measured with the 150 Hz tone filter specified in 2.15.4.

Note 3.— This column applies to the difference in peak frequency deviation between the separate measurements of the undesired 90 Hz FM (or equivalent PM) and the 150 Hz FM (or equivalent PM) obtained with the filters specified in the table in 2.15.4. The equivalent deviation for 90 Hz and 150 Hz measured PM values is calculated by multiplying each peak PM measurement in radians by its corresponding modulating frequency in Hz.

3. Material concerning VOR/DVOR

3.1 Guidance relating to VOR/DVOR equivalent isotropically radiated power (EIRP) and coverage

Note.— Unless specifically mentioned, all guidance material provided below applies to VOR and DVOR signals.

3.1.1 The field strength specified at Chapter 3, 3.3.4.2, is based on the following consideration:

Airborne receiver sensitivity	–117 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+7 dB
Power required at antenna	–110 dBW

The power required of minus 110 dBW is obtained at 118 MHz with a power density of minus 107 dBW/m^2; minus 107 dBW/m^2 is equivalent to 90 microvolts per metre, i.e. plus 39 dB referenced to 1 microvolt per metre.

Note.— The power density for the case of an isotropic antenna may be computed in the following manner:

$$P_d = P_a - 10 \log \frac{\lambda^2}{4\pi}$$

where

P_d = *power density in dBW/m²;*

P_a = *power at receiving point in dBW;*

λ = *wavelength in metres.*

3.1.2 The necessary EIRP to achieve a field strength of 90 microvolts per metre (minus 107 dBW/m^2) is given in Figure C-13. The field strength is directly proportional to the antenna elevation pattern. The actual radiation patterns of the antennas depend on a number of factors such as height of the antenna phase centre above ground level (AGL), surface roughness, terrain form and conductivity of ground and counterpoise. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, a conservative value has been provided. Whenever more precise system data are available, a more precise estimation of range is permissible. Further guidance may be found in the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies* (Doc 9718).

3.2 Guidance in respect of siting of VOR

3.2.1 VOR is susceptible to multipath interference from surrounding terrain, buildings, trees and power lines. The effect of this should therefore be considered when selecting a site for a new facility, and when considering the acceptability of proposed developments in the vicinity of established sites. Doppler VOR is more resistant to multipath interference than conventional VOR and may be used to provide acceptable performance on more challenging multipath sites.

Note.— Guidance on siting of VOR is given in documents EUROCAE ED-52 (including Amendment No. 1), United States Federal Aviation Administration Order 6820.10 and ICAO EUR DOC 015 (First Edition).

3.2.2 The impact of wind farm developments on VOR is an increasing problem in many States due to the growth of interest in alternative energy sources. The impact of wind farms on VOR is difficult to assess for several reasons, including:

a) the cumulative effect of a group of turbines may be unacceptable even though the effect of each of the turbines may be acceptable individually;

b) worst-case errors may be experienced when the turbine blades are stationary (due to either high or low wind speeds). The actual error is a function of the orientation of the turbine and position of the turbine blades when stationary;

c) worst-case errors are likely to be experienced at the limit of coverage and at low elevation angles; and

d) it is unlikely that the worst-case errors can be confirmed by flight inspections due to the factors listed above.

3.2.3 Computer simulations can be used to assess the effect of wind farms on VOR using worst-case assumptions, as outlined above.

3.3 [Reserved]

3.4 Criteria for geographical separation of VOR type facilities

3.4.1 In using the figures listed in Table C-3, it must be noted that these are derived from the agreed formulae in respect of specific altitudes. In application of the figures, regional meetings would only afford protection to the extent of the operationally required altitude and distance and, by use of the formulae, criteria can be calculated for any distance or altitude.

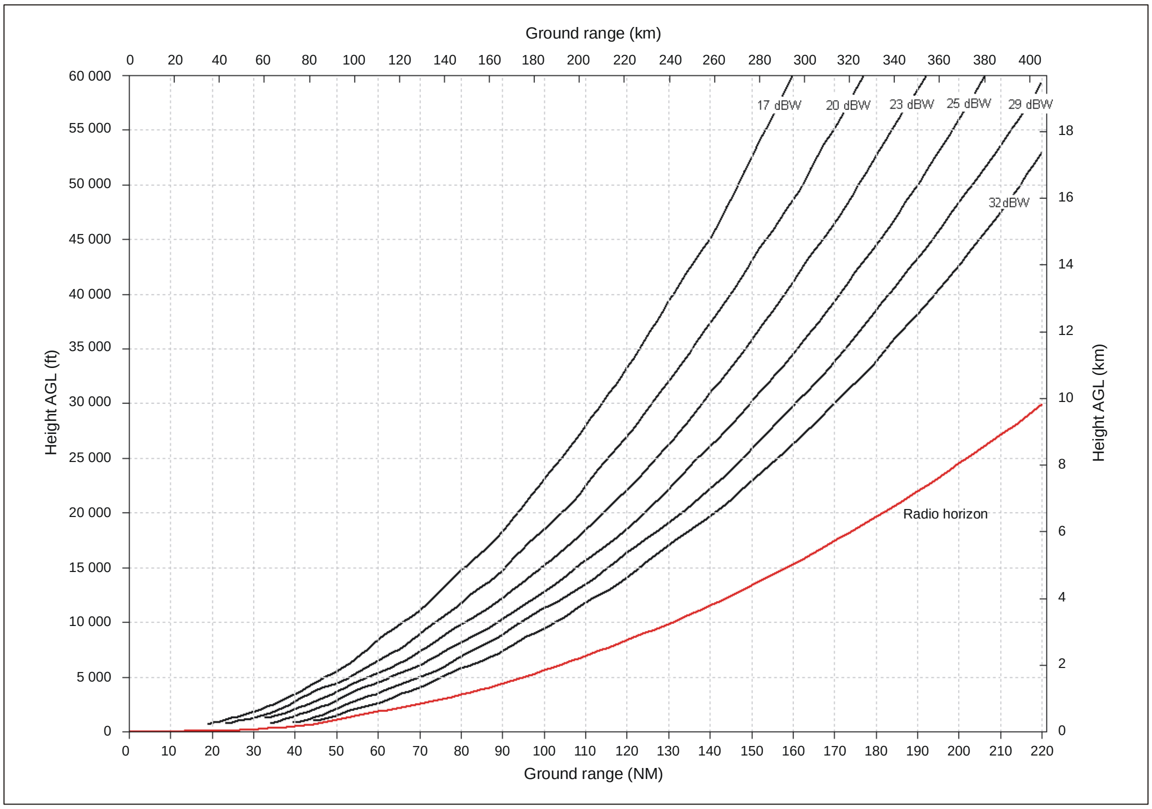


Figure C-13. Necessary EIRP to achieve a field strength of 90 microvolts per metre (-107 dBW/m^2) as a function of height above and distance from the VOR/DVOR

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.

Note 2.— The guidance provided assumes that the VOR/DVOR counterpoise height above ground level (AGL) that defines the antenna pattern is at 3 m (10 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— The transmitted power required to achieve an EIRP value as shown depends upon transmitting antenna gain and cable losses. As an example, an EIRP of 25 dBW can be achieved by a VOR with an output power of 100 W, a cable loss of 1 dB and an antenna gain of 6 dBi.

3.4.2 The figures listed are calculated on the assumption that the effective adjacent channel rejection of the airborne receiver is better than 60 dB down at the next assignable channel.

3.4.3 The calculations are based on the assumption that the protection against interference afforded to the wanted signal from the unwanted signal is 20 dB, corresponding to a bearing error of less than 1 degree due to the unwanted signal.

3.4.4 It is recognized that, in the case of adjacent channel operation, there is a small region in the vicinity of a VOR facility, in which interference may be caused to an aircraft using another VOR facility. However, the width of this region is so small that the duration of the interference would be negligible and, in any case, it is probable that the aircraft would change its usage from one facility to the other.

3.4.5 The agreed formulae for calculating the geographical separations are as follows (nautical miles may be substituted for kilometres):

A — *minimum geographical separation (co-channel):*

either $2\,D_1 + \frac{20-K}{S}$ km

where $D_1 > D_2 + \frac{K}{S}$

or $2\,D_2 + \frac{20+K}{S}$ km

where $D_1 < D_2 + \frac{K}{S}$

B — *geographical separation (adjacent channel):*

collocation case

$< \frac{40-K}{S}$

non-collocated case

$> 2D_1 - \frac{40+K}{S}\ km$

where $D_1 > D_2 + \frac{K}{S}$

or $2D_2 - \frac{40-K}{S}\ km$

where $D_1 < D_2 + \frac{K}{S}$

C — *geographical separation (adjacent channel)*
(receivers designed for 100 kHz channel spacing in a 50 kHz channel spacing environment)

If receivers having an effective adjacent channel rejection of no better than 26 dB are used (e.g. a 100 kHz receiver used in a 50 kHz environment), a figure of 6 should be substituted for the figure of 40 in the above adjacent channel formulae. In this instance, the geographical collocation formula should not be used as the protection afforded may be marginal.

This leads to the following formula:

$> 2D_1 + \frac{6+K}{S}\ km$

where $D_1 > D_2 + \frac{K}{S}$

or $2D_2 - \frac{6-K}{S}\ km$

where $D_1 < D_2 + \frac{K}{S}$

Table C-3. Values of geographical separation distances for co-channel operation

		VOR facilities of equal effective radiated power		VOR facilities which differ in effective radiated power by 6 dB				VOR facilities which differ in effective radiated power by 12 dB			
		Minimum geographical separation between facilities is $2D_1 + \frac{20}{S}$ *if* $D_1 > D_2$ or $2D_2 + \frac{20}{S}$ *if* $D_2 > D_1$		Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ *if* $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ *if* $D_1 < D_2 + \frac{K}{S}$				Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ *if* $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ *if* $D_1 < D_2 + \frac{K}{S}$			
Altitude m (ft)	S dB/km (NM)	K dB	$\frac{20}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)
1	2	3	4	5	6	7	8	9	10	11	12
1 200 (4 000)	0.32 (0.60)	0	61 (33)	6	19 (10)	43 (23)	80 (43)	12	37 (20)	24 (13)	98 (53)
3 000 (10 000)	0.23 (0.43)	0	87 (47)	6	26 (14)	61 (33)	113 (61)	12	52 (28)	35 (19)	137 (74)
4 500 (15 000)	0.18 (0.34)	0	109 (59)	6	33 (18)	76 (41)	143 (77)	12	67 (36)	44 (24)	174 (94)
6 000 (20 000)	0.15 (0.29)	0	128 (69)	6	39 (21)	89 (48)	167 (90)	12	78 (42)	52 (28)	206 (110)
7 500 (25 000)	0.13 (0.25)	0	148 (80)	6	44 (24)	104 (56)	193 (104)	12	89 (48)	59 (32)	237 (128)
9 000 (30 000)	0.12 (0.23)	0	161 (87)	6	48 (26)	113 (61)	209 (113)	12	96 (52)	65 (35)	258 (139)
12 000 (40 000)	0.10 (0.19)	0	195 (105)	6	59 (32)	135 (73)	254 (137)	12	119 (64)	78 (42)	311 (168)
18 000 (60 000)	0.09 (0.17)	0	219 (118)	6	65 (35)	154 (83)	284 (153)	12	130 (70)	87 (47)	348 (188)

Note.— S, K and the sign of K are defined in 3.4.5.

In the above formulae:

D_1, D_2 = service distances required of the two facilities (km).

K = the ratio (dB) by which the effective radiated power of the facility providing D_1 coverage exceeds that of the facility providing D_2 coverage.

Note.— If the facility providing D_2 is of higher effective radiated power, then "K" will have a negative value.

S = slope of the curve showing field strength against distance for constant altitude (dB/km).

3.4.6 The figures listed in Table C-3 are based on providing an environment within which the airborne receivers can operate correctly.

3.4.6.1 In order to protect VOR receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

3.4.6.2 In order to protect VOR receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

3.4.7 Use of the figures given in 3.4.6 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. The assumptions include that the change of field strength with distance (Factor "S") at various altitudes of reception is only valid for angles of elevation at the VOR of up to about 5 degrees, but above the radio line of sight. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves.

3.4.8 The deployment of 50 kHz channel spacing requires conformity with Chapter 3, 3.3.2.2 and 3.3.5.7 and Annex 10, Volume V, Chapter 4, 4.2.4. Where, due to special circumstances it is essential during the initial conversion period from 100 kHz channel spacing to 50 kHz channel spacing to take account of nearby VOR facilities that do not conform with Chapter 3, 3.3.2.2 and 3.3.5.7 and Annex 10, Volume V, Chapter 4, 4.2.4, greater geographical separation between these and the new facilities utilizing 50 kHz channel spacing will be required to ensure a bearing error of less than one degree due to the unwanted signal. On the assumption that the sideband levels of the 9 960 Hz harmonic of the radiated signal of such facilities do not exceed the following levels:

9 960 Hz	0 dB reference
2nd harmonic	–20 dB
3rd harmonic	–30 dB
4th harmonic and above	–40 dB

the separation formulae at 3.4.5 should be applied as follows:

a) where only receivers designed for 50 kHz channel spacing need to be protected, the value of 40 should be replaced by 20 in the formula at B — non-collocated case;

b) where it is necessary to protect receivers designed for 100 kHz channel spacing, the co-channel formula at A — co-channel case, should be applied for the range of altitudes for which protection is required.

3.4.9 When DME/N facilities and VOR facilities are intended to operate in association with each other, as outlined in Chapter 3, 3.5.3.3.4, and have a common service volume, both the co-channel and adjacent channel geographical separation distances required by the DME are satisfied by the separation distances of the VOR as computed in this section, provided the distance between VOR and DME does not exceed 600 m (2 000 ft). A potential interference situation may also occur with the implementation of DME "Y" channels since interference between two DME ground stations spaced 63 MHz apart could occur when transmitting and receiving on the same frequency (e.g. transmissions from channel 17 Y could interfere with reception on channels 80 X and 80 Y). To obviate any ground receiver desensitization due to this interference, a minimum ground separation distance of 18.5 km (10 NM) between facilities is necessary.

3.5 Criteria for geographical separation of VOR/ILS facilities

3.5.1 In using the figures of 3.5.3.1 and 3.5.3.2, it is to be borne in mind that the following assumptions have been made:

a) that the localizer receiver characteristic is as shown in 2.6.2, and the VOR receiver characteristic as shown in 3.4.2;

b) that the protection ratio for the ILS system and the VOR system is 20 dB as in 2.6.4 and 3.4.3, respectively;

c) that the protection point for ILS is at a service distance of 46.25 km (25 NM) measured along the line of use, and at an altitude of 1 900 m (6 250 ft).

Note.— With the advent of highly directional ILS localizer antenna arrays, the most critical protection point will not be along the extended runway centre line. Directive antennas result in critical protection points at maximum distance, either plus or minus 10 degrees or plus or minus 35 degrees off the runway centre line. Protection of these points should be examined during the frequency assignment process.

3.5.2 Although international VOR and ILS facilities will not appear on the same frequency, it may occur that an international VOR facility may share temporarily the same frequency as, and on a comparable basis with, a national ILS facility. For this reason, guidance is given as to the geographical separation required not only for a VOR and an ILS facility separated by 50 kHz or 100 kHz, but also for co-channel usage.

3.5.3 Because of the differing characteristics of use of the two equipments, the criteria for minimum geographical separation of VOR/ILS to avoid harmful interference are stated separately for each facility where relevant.

3.5.3.1 *Co-channel case*

a) Protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 148 km (80 NM) from the ILS protection point.

b) On the assumption that a VOR having an ERP of 17 dBW (50 W) is to be protected to a service distance of 46.25 km (25 NM) and an altitude of 3 000 m (10 000 ft), protection of the VOR system requires that the ILS be at least 148 km (80 NM) from the VOR.

c) If protection of the VOR is required to, say, 92.5 km (50 NM) and 6 000 m (20 000 ft), the ILS is to be at least 250 km (135 NM) from the VOR.

3.5.3.2 *Adjacent channel case.* Protection of the VOR system is effectively obtained without geographical separation of the facilities. However, in the case of:

a) a localizer receiver designed for 100 kHz channel spacing and used in an area where navaid assignments are spaced at 100 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 9.3 km (5 NM) from the ILS protection point;

b) a localizer receiver designed for 100 kHz channel spacing and used in an area where assignments are spaced at 50 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 79.6 km (43 NM) from the ILS protection point.

3.5.4 Use of the figures given in 3.5.3 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves.

3.5.5 Protection of the ILS system from VOR interference is necessary where a VOR facility is located near an ILS approach path. In such circumstances, to avoid disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be used. The frequency separation will be dependent upon the ratio of the VOR and ILS field densities, and the characteristics of the airborne installation.

3.6 Receiving function

3.6.1 *Sensitivity.* After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions the accuracy of output specified in 3.6.2, with a signal having a field strength of 90 microvolts per metre or minus 107 dBW/m^2.

3.6.2 *Accuracy.* The error contribution of the airborne installation should not exceed plus or minus 3 degrees with a 95 per cent probability.

Note 1.— The assessment of the error contribution of the receiver will need to take account of:

1) the tolerance of the modulation components of the ground VOR facility as defined in Chapter 3, 3.3.5;

2) variation in signal level and carrier frequency of the ground VOR facility;

3) the effects of unwanted VOR and ILS signals.

Note 2.— The airborne VOR installation is not considered to include any special elements which may be provided for the processing of VOR information in the aircraft and which may introduce errors of their own (e.g. radio magnetic indicator (RMI).).

3.6.3 *Flag alarm operation.* Ideally, the flag alarm should warn a pilot of any unacceptable malfunctioning conditions which might arise within either the ground or airborne equipments. The extent to which such an ideal might be satisfied is specified below.

3.6.3.1 The flag alarm movement is actuated by the sum of two currents which are derived from the 30 Hz and 9 960 Hz elements of the VOR bearing component signal and, therefore, the removal of these elements from the radiated carrier results in the appearance of the flags. Since the VOR ground monitor interrupts the bearing components when any unacceptable condition prevails on the ground, there will be an immediate indication within an aircraft when the system is unusable.

3.6.3.2 The flag alarm movement current is also dependent upon the AGC characteristics of the airborne equipment and any subsequent gain following the receiver’s second detector. Thus, if with a correctly adjusted airborne receiver the flag is just out of view when receiving a VOR signal conforming to the modulation characteristics specified in Chapter 3, 3.3.5, the flags will again become visible in the event of a decrease in the receiver’s overall gain characteristics.

Note.— Certain types of receivers employ warning indications other than mechanical flags to perform the functions described here.

3.6.4 *VOR receiver susceptibility to VOR and localizer signals*

3.6.4.1 The receiver design should provide correct operation in the following environment:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB (during bench testing of the receiver, in this first adjacent channel case, the undesired signal is varied over the frequency range of the combined ground station (plus or minus 9 kHz) and receiver frequency tolerance);

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

Note 1.— It is recognized that not all receivers currently meet requirement b); however, all future equipments are designed to meet this requirement.

Note 2.— In some States, a smaller ground station tolerance is used.

3.6.5 *Immunity performance of VOR receiving systems to interference from VHF FM broadcast signals*

3.6.5.1 With reference to Chapter 3, 3.3.8, the immunity performance defined therein must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Additional information can be found in ITU Recommendation ITU-R SM.1140, *Test procedures for measuring aeronautical receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–118 MHz*.

Note.— Receiver test procedures are also given in the VOR receiver MOPS (RTCA DO-196, and EUROCAE ED-22B).

3.6.5.2 Commonly agreed formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3, 3.3.8. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R IS.1009-1, *Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–137 MHz*.

3.7 VOR system accuracy

Note.— Guidance material on the determination of VOR system performance values is also contained in Annex 11, Attachment A.

3.7.1 *Purpose.* The following guidance material is intended to assist in the use of VOR systems. It is not intended to represent lateral separation standards or minimum obstacle clearances, although it may of course provide a starting point in their determination. The setting of separation standards or minimum obstacle clearances will necessarily take account of many factors not covered by the following material.

3.7.1.1 There is, however, a need to indicate a system use accuracy figure for the guidance of States planning VOR systems.

3.7.2 *Explanation of terms.* The following terms are used with the meanings indicated:

a) *VOR radial signal error.* The difference between the nominal magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by the VOR signal at that same point. The VOR radial signal error is made up of certain stable elements, such as course displacement error and most site and terrain effect errors, and certain random variable errors. The VOR radial signal error is associated with the ground station only and excludes other error factors, such as airborne equipment errors and pilotage element.

b) *VOR radial variability error.* That part of the VOR radial signal error which can be expected to vary about the essentially constant remainder. The radial variability error is the sum of the variable errors.

c) *VOR radial displacement error.* That part of the VOR radial signal error which is stable and may be considered as fixed for long periods of time.

d) *VOR airborne equipment error.* That error attributable to the inability of the equipment in the aircraft to translate correctly the bearing information contained in the radial signal. This error includes the contributions of the airborne receiver and the instrumentation used to present the information to the pilot.

e) *VOR aggregate error.* The difference between the magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by airborne VOR equipment of stated accuracy. More simply put, this is the error in the information presented to the pilot, taking into account not only the ground station and propagation path errors, but also the error contributed by the airborne VOR receiver and its instrumentation. The entire VOR radial signal error, both fixed and variable, is used.

f) *VOR pilotage element.* The error in the use of VOR navigation attributable to the fact that the pilot cannot or does not keep the aircraft precisely at the centre of the VOR radial or bearing indicated by the equipment.

g) *VOR system use error.* The square root of the sum of the squares (RSS) of VOR aggregate error and the pilotage element. This combination may be used to determine the probability of an aircraft remaining within specified limits when using VOR.

3.7.3 *Calculation of VOR system use accuracy*

3.7.3.1 The VOR system use accuracy is derived by considering the following error elements:

a) *VOR radial signal error* (Eg). This element consists of the radial displacement error and the radial variability error. It is determined by considering such factors as fixed radial displacement, monitoring, polarization effects, terrain effects and environment changes.

b) *VOR airborne equipment error* (Ea). This element embraces all factors in the airborne VOR system which introduces errors (errors resulting from the use of compass information in some VOR displays are not included).

c) *VOR pilotage element* (Ep). The value taken for this element is that used in PANS-OPS (Doc 8168) for pilot tolerance.

Note.— A measurement error also exists, but in a generalized discussion of errors may be considered to be absorbed in the other error values.

3.7.3.2 Since the errors in a), b), and c), when considered on a system basis (not any one radial) are independent variables, they may be combined on a root-sum-square method (RSS) when the same probability level is given to each element. For the purpose of this material, each element is considered to have a 95 per cent probability.

Therefore, the following formulae are derived:

$$\text{VOR aggregate error} = \sqrt{\mathrm{Eg}^2 + \mathrm{Ea}^2}$$

$$\text{VOR system use error} = \sqrt{\mathrm{Eg}^2 + \mathrm{Ea}^2 + \mathrm{Ep}^2}$$

3.7.3.3 The following examples will derive only the VOR system use error but calculations can also be made to determine VOR aggregate error, if desired. By use of these formulae, the impact on the system of improvement or degradation of one of more error elements can be assessed.

Note.— All figures for VOR radial signal error are related to radials for which no restrictions are published.

3.7.3.4 Subject to the qualifications indicated in 3.7.1, it is considered that a VOR system use accuracy of plus or minus 5 degrees on a 95 per cent probability basis is a suitable figure for use by States planning the application of the VOR system (see, however, 3.7.3.5). This figure corresponds to the following component errors:

VOR radial signal error:

plus or minus 3° (95 per cent probability), a value readily achieved in practice.

VOR airborne equipment error:

plus or minus 3° (95 per cent probability), system characteristics value (see 3.6.2).

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

3.7.3.5 While the figure of plus or minus 5 degrees on a 95 per cent probability basis is a useful figure based on broad practical experience and used by many States, it must be noted that this figure may be achieved only if the error elements which make it up remain within certain tolerances. It is clear that, if the errors attributable to the VOR system elements are larger than the amounts noted, the resulting VOR system use error will also be larger. Conversely, where any or all of the VOR system error elements are smaller than those used in the above computation, the resulting VOR system use error will also be smaller.

3.7.3.6 The following examples, also derived from practical experience, provide additional planning guidance for States:

A.— *VOR radial signal error:*

plus or minus 3.5° (95 per cent probability), used by some States as the total ground system error.

VOR airborne equipment error:

plus or minus 4.2° (95 per cent probability), recognized in some States as the minimum performance figure for some classes of operations.

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

Calculated VOR system use accuracy:

plus or minus 6° (95 per cent probability).

B. — *VOR radial signal error:*

plus or minus 1.7° (95 per cent probability), based on extensive flight measurements conducted in one State on a large number of VORs.

VOR airborne equipment error:

plus or minus 2.7° (95 per cent probability), achieved in many airline operations.

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

Calculated VOR system use accuracy:

plus or minus 4° (95 per cent probability).

3.7.3.7 More realistic application of the VOR system may be achieved by assessing the errors as they actually exist in particular circumstances, rather than by using all-embracing generalizations which may give unduly optimistic or pessimistic results. In individual applications, it may be possible to utilize a system use accuracy value less than plus or minus 5 degrees if one or more of the error elements are smaller than the values used to compute the plus or minus 5 degrees. Conversely, a system use accuracy value greater than plus or minus 5 degrees will be necessary where it is known that radials are of poor quality or significant site errors exist, or for other reasons. However, in addition to this advice a warning is also essential regarding the use of lower values of individual elements in the system (for example, the radial signal error) on the assumption that an overall improvement in system accuracy will occur. There is considerable evidence that this may not be the case in some circumstances and that lower system accuracy values should not be applied without other confirmation (e.g. by radar observation) that an actual improvement in overall performance is being achieved.

3.7.3.8 It is to be noted that in angular systems such as the VOR, the pilotage element error, expressed in angular terms, will be greater as the aircraft nears the point source. Thus, while ground system and airborne error contributions, expressed in angular terms, are for all practical purposes constant at all ranges, it is necessary when considering the overall system use accuracy figures to take into account the larger pilotage element error occurring when the aircraft is near the VOR. However, these larger pilotage element errors do not result in large lateral deviations from course when near the facility.

3.8 Changeover points for VORs

Guidance on the establishment of changeover points on ATS routes defined by VORs is contained in Annex 11, Attachment A.

4. Precision approach radar system

Figures C-14 to C-18 illustrate certain of the Standards contained in Chapter 3, 3.2.

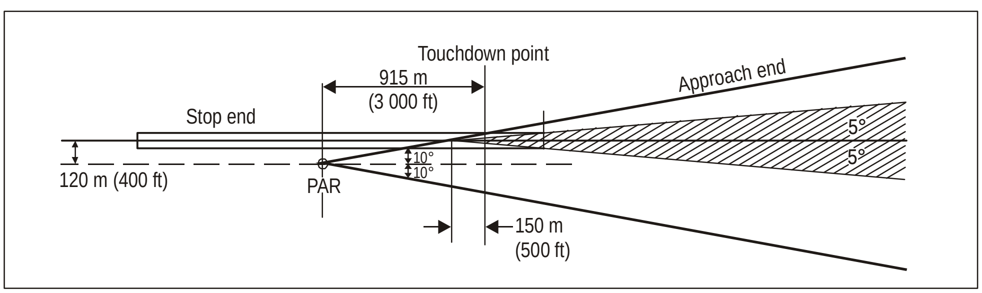


Figure C-14. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

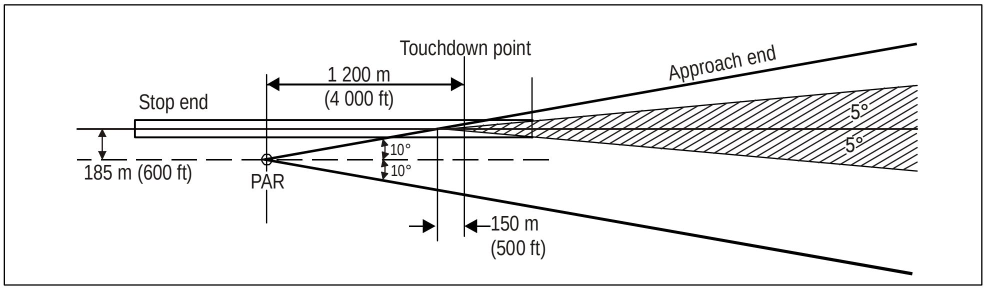


Figure C-15. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

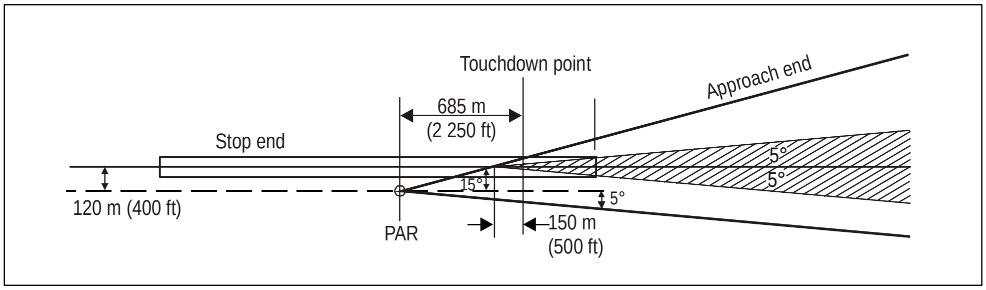


Figure C-16. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan 5 degrees and 15 degrees on QDR of runway

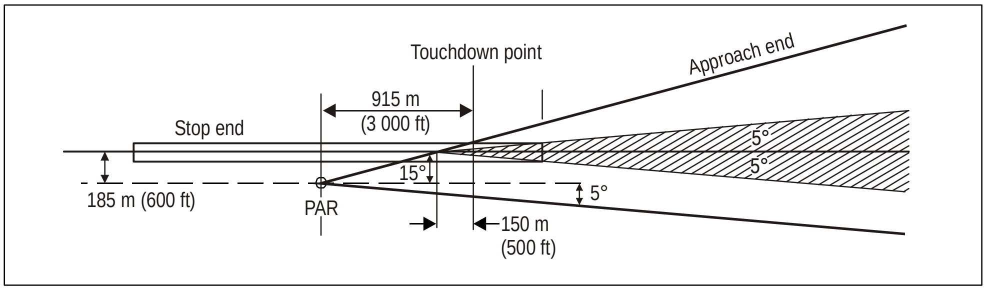


Figure C-17. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan 5 degrees and 15 degrees on QDR of runway

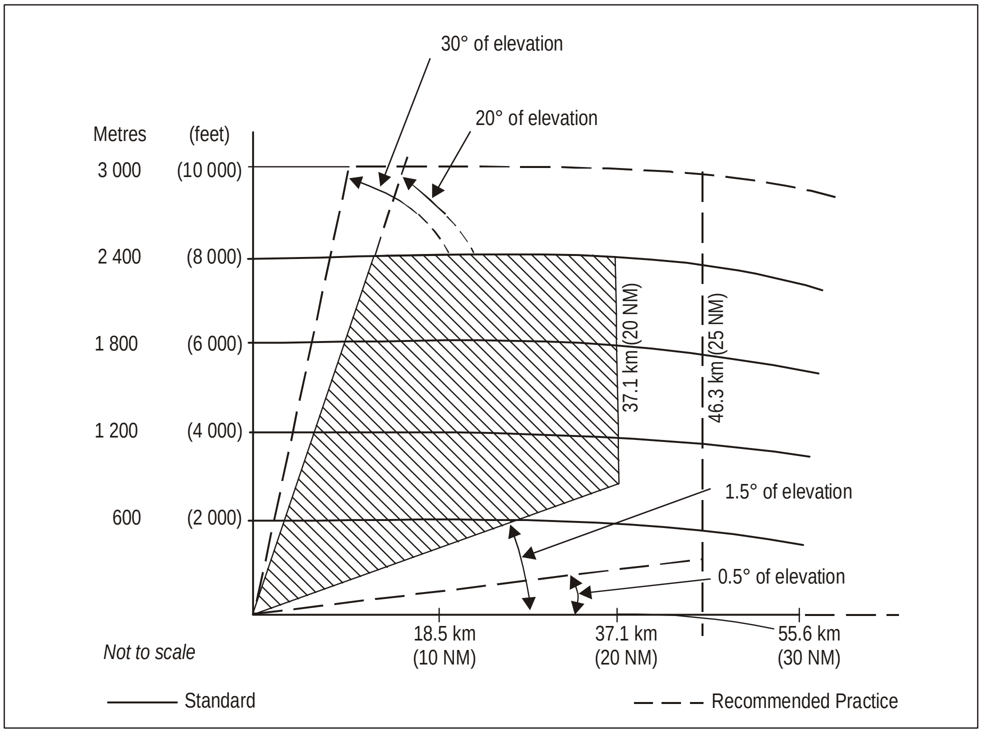


Figure C-18. SRE of precision approach radar system — vertical coverage on a 15 m^2 echoing area aircraft

5. Specification for 75 MHz marker beacons (en-route)

5.1 Marker beacon antenna arrays

5.1.1 *General.* The following describes types of marker antenna arrays that are frequently used in current practice. These types are the simplest forms meeting normal requirements; in special cases, arrays having a better performance (see Note to 5.1.4) may be required.

5.1.2 *Z marker beacons*

a) *Radiating system.* A radiating system consisting of two horizontal dipole arrays crossed at right angles, each comprising two co-linear half-wave radiating elements with centres spaced approximately a half wavelength apart and mounted one-quarter wavelength above the counterpoise. The currents in the dipoles and their respective elements are adjusted so that:

1) the current in one set of dipole arrays relative to that in the other set is equal but differs in time phase by 90 degrees;

2) the currents in the radiating elements of a particular dipole array are equal and in time phase.

b) *Counterpoise.* A square counterpoise with minimum dimensions of 9 m × 9 m, usually elevated about 1.8 m (6 ft) above the ground and, if fabricated from wire mesh, with the dimension of the mesh not exceeding 7.5 cm × 7.5 cm.

5.1.3 *Fan marker beacons for use only at low altitudes (low power fan marker beacons).* A radiating system capable of providing the field strengths indicated in Chapter 3, 3.1.7.3.2.

5.1.4 *Fan marker beacons for general use (high power fan marker beacons)*

a) *Radiating system.* A radiating system consisting of four horizontal co-linear half-wave (approximate) radiating elements mounted approximately one-quarter wavelength above the counterpoise. The current in each of the antenna elements should be in phase and should have a current ratio of 1:3:3:1.

   Note.— The current distribution between elements and their height above the counterpoise may be altered to provide patterns for specific operational requirements. Improved vertical patterns for certain operational needs may be achieved by adjusting the height of the dipole arrays above the counterpoise to a value of one-quarter wavelength or greater, but less than a half wavelength.

b) *Counterpoise.* A rectangular counterpoise with minimum dimensions of 6 m × 12 m, usually elevated about 1.8 m (6 ft) above the ground and, if fabricated from wire mesh, with the dimension of the mesh not exceeding 7.5 cm × 7.5 cm.

5.2 Identification coding for fan marker beacons associated with a four-course radio range

5.2.1 Fan marker beacons located on the legs of a four-course radio range do not normally require an identification signal relating to a particular geographic location, but only a signal that will indicate the leg with which they are associated.

5.2.2 In the case of a four-course radio range having not more than one marker on any leg, it is current practice to identify a marker by a single dash if on the leg bearing true north or nearest to north in a clockwise direction (east), and to identify a marker on other legs by two, three or four dashes according to whether the leg with which it is associated is the second, third or fourth leg from north in a clockwise direction. Where more than one fan marker beacon is associated with one leg of a four-course radio range, the marker nearest to the station is identified by dashes only, the next nearest by two dots preceding the dashes, and the third by three dots preceding the dashes, and so on.

Note.— In certain special circumstances, the above coding system may lead to ambiguities due to two markers associated with the legs of different but overlapping radio ranges being geographically close together. In such cases, it is desirable to use a distinctive identification coding with one of the marker beacons.

6. Material concerning NDB

6.1 Guidance material on NDB field strength requirements in latitudes between 30°N and 30°S

6.1.1 In order to obtain a satisfactory service within the rated coverage of an NDB located in latitudes between 30°N and 30°S, a minimum value of field strength of 120 microvolts per metre would be required, except where practical experience in the operation of NDBs over several years has revealed that a minimum field strength of 70 microvolts per metre would be adequate to meet all the operational needs. In some specific areas, field strength values considerably in excess of 120 microvolts per metre would be required. Such areas are:

a) Indonesia and Papua New Guinea, Myanmar, Malay Peninsula, Thailand, Lao People's Democratic Republic, Democratic Kampuchea, Viet Nam and Northern Australia;

b) Caribbean and northern parts of South America;

c) Central and South Central Africa.

6.1.2 The field strength of 120 microvolts per metre is based upon practical experience to date and is a compromise between what is technically desirable and what it is economically possible to provide.

6.2 Guidance material on meaning and application of rated and effective coverage

6.2.1 *Rated coverage*

6.2.1.1 The rated coverage as defined in Chapter 3, 3.4.1, is a means of designating actual NDB performance, in a measurable way, which is dependent on the frequency, the radiated power, and the conductivity of the path between the NDB and a point on the boundary where the minimum value of field strength is specified.

6.2.1.2 The rated coverage has been found to be a useful means of facilitating regional planning and, in some instances, may be related to effective coverage.

6.2.1.3 The application of rated coverage to frequency planning is governed by the following criteria:

6.2.1.3.1 Frequencies should be deployed having regard to the rated coverage of the NDBs concerned, so that the ratio of the signal strength of any NDB at the boundary of its rated coverage to the total field strength due to co-channel stations and adjacent channel stations (with an appropriate allowance for the selectivity characteristics of a typical airborne receiver) is not less than 15 dB by day.

6.2.1.3.2 The figures set forth in Attachment B to Volume V of Annex 10 should be applied, as appropriate, in determining the allowance to be made for the attenuation of adjacent channel signals.

6.2.1.4 It follows from the application of rated coverage to frequency deployment planning that, unless otherwise specified, protection against harmful interference can only be ensured within the rated coverage of an NDB and, then, only if the radiated power of the NDBs is adjusted to provide within reasonably close limits the field strength required at the limit of the rated coverage. In areas where the density of NDBs is high, any NDB providing a signal at the limit of its rated coverage materially in excess of that agreed in the region concerned will give rise, in general, to harmful interference within the rated coverages of cochannel or adjacent channel NDBs in the area concerned, and will limit the number of NDBs which can be installed in the region within the available spectrum. It is important, therefore, that increases in radiated power beyond that necessary to provide the rated coverage, particularly at night when sky wave propagation may give rise to interference over long distances, should not be made without coordination with the authorities of the other stations likely to be affected (see Chapter 3, 3.4.3).

6.2.1.5 Frequency planning is considerably facilitated if a common value of minimum field strength within the desired coverage is used.

6.2.1.6 Extensive experience has shown that in relatively low noise level areas, such as Europe, the figure of 70 microvolts per metre is satisfactory.

6.2.1.6.1 Experience has also shown that the figure of 120 microvolts per metre is generally satisfactory for higher noise level areas but will be inadequate in areas of very high noise. In such areas, the information given in 6.3 may be used for general guidance.

6.2.2 *Relationship to effective coverage*

6.2.2.1 Rated coverage may have a close correlation to effective coverage under the following conditions:

a) when the minimum field strength within the rated coverage is such that, for most of the time, it exceeds the field strength due to atmospheric and other noise sufficiently to ensure that the latter will not distort the information presented in the aircraft to the extent that it is unusable;

b) when the ratio of the strength of the wanted signal to that of interfering signals exceeds the minimum required value at all points within the coverage, in order to ensure that interfering signals will also not distort the information presented in the aircraft to the extent that it is unusable.

6.2.2.2 Since, normally, the lowest signal within the coverage will occur at its boundary, these conditions imply that at the boundary the field strength should be such that its ratio to atmospheric noise levels would ensure usable indications in the aircraft for most of the time and that, in respect of the boundary value, overall planning should ensure that the ratio of its value to that of interfering signals exceeds the required value for most of the time.

6.2.2.3 Although the value of 70 microvolts per metre used for frequency deployment has been found successful in Europe (i.e. north of 30° latitude) in giving coverage values which closely approximate to effective coverage most of the time, experience is too limited to prove the suitability of the 120 microvolts per metre value for general application in areas of high noise. It is to be expected that rated coverages in high noise based on a boundary value of 120 microvolts per metre will, on many occasions, be substantially greater than the effective coverage achieved. In such areas, in order to secure a better correlation between rated coverage and an average of the achieved effective coverage, it may be advisable to choose a boundary value based more closely on the proportionality of noise in that area to the noise in areas where a boundary value has been satisfactorily established (e.g. Europe), or to determine an appropriate value from a statistical examination of achieved effective coverages in respect of an NDB in the area of known performance.

6.2.2.4 It is important to appreciate, however, that minimum values of field strength based on a simple comparison of noise levels in different areas may be insufficient, because factors such as the frequency of occurrence of noise, its character and effect on the airborne receiver and the nature of the air operation involved may all modify ratios determined in this way.

6.2.2.5 Values of diurnal and seasonal noise in various parts of the world have been published in Report 322 of the former CCIR of the ITU.

6.2.2.5.1 Correlation of these values to actual local conditions and the derivation of required signal-to-noise ratios for effective operational use of ADF equipment is not yet fully established.

6.2.3 *Effective coverage*

6.2.3.1 Effective coverage as defined in Chapter 3, 3.4.1, is the area surrounding an NDB, within which useful information to the operator concerned can be obtained at a particular time. It is, therefore, a measure of NDB performance under prevailing conditions.

6.2.3.2 The effective coverage is limited by the ratio of the strength of the steady (non-fading) signal received from the NDB to the total noise intercepted by the ADF receiver. When this ratio falls below a limiting value, useful bearings cannot be obtained. It should also be noted that the effective coverage of an NDB may in some cases be limited to the range of the usable identification signal.

6.2.3.3 The strength of signal received from the NDB is governed by:

a) the power supplied to the antenna of the NDB;

b) the radiation efficiency of the antenna, which varies according to the height of the antenna and other characteristics of the radiating system;

c) the conductivity of the path between the NDB and the receiver, which may vary considerably as between one site and another, and is always less over land than over seawater;

d) the operating radio frequency.

6.2.3.4 The noise admitted by the receiver depends on:

a) the bandwidth of the receiver;

b) the level of atmospheric noise, which varies according to the geographical area concerned, with the time of day and the season of the year, and which may reach very high levels during local thunderstorms;

c) the level of the interference produced by other radio emissions on the same or on adjacent frequencies, which is governed to a large extent by the NDB density in the area concerned and the effectiveness of regional planning;

d) the level of noise due to electrical noise in the aircraft or to industrial noise (generated by electric motors, etc.), when the coverage of the NDB extends over industrial areas.

6.2.3.4.1 It has to be noted that the effect of noise depends on characteristics of the ADF receiver and the associated equipment, and also on the nature of the noise (e.g. steady noise, impulsive noise).

6.2.3.5 A further factor which limits the effective coverage of an NDB is present at night when interaction occurs between components of the signal which are propagated respectively in the horizontal plane (ground wave propagation) and by reflection from the ionosphere (sky wave propagation). When there is interaction between these components, which arrive at the ADF receiver with a difference of phase, bearing errors are introduced (night effect).

6.2.3.6 It will thus be seen that the effective coverage of an NDB depends on so many factors, some of which are variable, that it is impossible to specify the effective coverage of an NDB in any simple manner. The effective coverage of any NDB, in fact, varies according to the time of day and the season of the year.

6.2.3.6.1 Hence any attempt to specify an effective coverage, which would be obtainable at any time throughout the day or throughout the year, would result either in a figure for coverage which would be so small (since this would be the coverage obtained under the worst conditions of atmospheric noise, etc.) as to give quite a misleading picture of the effectiveness of the NDB, or would involve such high power and costly antenna systems (to provide the required coverage under the worst conditions), that the installation of such an NDB would usually be precluded by considerations of initial and operating costs. No specific formula can be given in determining what rated coverage would be equivalent to a desired effective coverage and the relation must be assessed regionally.

6.2.3.7 Those concerned with the operational aspects of NDB coverage will normally consider requirements in terms of a desired operational coverage and, in regional planning, it will usually be necessary to interpret such requirements in terms of a rated coverage from which may be derived the essential characteristics of the NDB required and which will also define the area to be protected against harmful interference. No specific formula can be given in determining what rated coverage would be equivalent to a desired operational coverage and the relation must be assessed regionally.

6.2.3.8 Some States have recorded data on NDBs and their effective coverage; and collection of similar information would be a practical way of obtaining an assessment of effective coverage in terms of rated coverage of facilities in a given area. This information would also be useful for future regional planning. In order to reduce the number of factors involved in assessing effective coverage, it would be desirable to establish criteria for determining the limit of useful coverage in terms of the reaction of the bearing indicator. The data referred to previously, together with measurements of actual field strength within the coverage of the NDB, would also permit determination of the effectiveness of existing installations and provide a guide to improvements that may be necessary to achieve a desired effective coverage.

6.3 Coverage of NDBs

6.3.1 *Introduction*

6.3.1.1 The following studies have been based on the latest propagation and noise data available to the ITU. They are included in this Attachment as general guidance in respect of NDB planning. Attention is called particularly to the assumptions made.

6.3.1.2 When applying the material, the validity of the assumptions in respect of the particular conditions under consideration should be carefully examined and, in particular, it should be noted that the assumed signal-to-noise ratios require considerable further study before they can be accepted as representative of the ratios limiting useful reception.

6.3.2 *Assumptions*

1. Operating frequency — 300 kHz.
   Reference is made, however, where appropriate, to frequencies of 200 kHz and 400 kHz.

2. a) Average soil conductivity:
   ($\sigma = 10^{-13}$ e.m.u.)

   b) Average seawater conductivity:
   ($\sigma = 4.10^{-11}$ e.m.u.)

3. The level of atmospheric noise (RMS) which is likely to prevail: 1) by day, 2) by night, over land masses, within the belts of latitude mentioned. [The values of expected noise have been derived from Recommendation ITU-R P.372-6 and have been taken as the average noise by day and by night during equinox periods, i.e. the values which are likely to be exceeded 20–25 per cent of the year.]

4. Input powers to the antenna of the NDB of:

   a) 5 kW
   b) 1 kW
   c) 500 W
   d) 100 W
   e) 50 W
   f) 10 W

5. The following average values of radiation efficiencies of antennas, i.e. the ratio of:

$$\left[\frac{\text{Radiated power}}{\text{Input power to antenna}}\right]$$

	Input power to antenna	*Radiation efficiency of antenna*
a)	5 kW	20% (–7 dB)
b)	5 kW	10% (–10 dB)
c)	1 kW	8% (–11 dB)
d)	500 W	5% (–13 dB)
e)	100 W	3% (–15 dB)
f)	50 W	2% (–17 dB)
g)	10 W	1% (–20 dB)
h)	10 W	0.3% (–25 dB)

i) The figure for a) is included because it is possible to realize this efficiency by the use of a more elaborate antenna system than is usually employed.

ii) The figure for h) is included because many low power NDBs use very inefficient antennas.

6. An admittance band of the ADF receiver of 6 kHz.

7. Required ratios of signal-(median) to-noise (RMS) of:

a) 15 dB by day;

b) 15 dB by night.

6.3.3 *Results of studies*

A.— *Minimum field strengths required at the boundary of the rated coverage:*

Latitude	*By day for 15 dB S/N ratio*	*By night for 15 dB S/N ratio*
5°N – 5°S	320 µV/m (+50 dB)	900 µV/m (+59 dB)
5° – 15°N&S	85 µV/m (+39 dB)	700 µV/m (+57 dB)
15° – 25°N&S	40 µV/m (+32 dB)	320 µV/m (+50 dB)
25° – 35°N&S	18★µV/m (+25 dB)	120 µV/m (+42 dB)
>35°N&S	18★µV/m (+25 dB)	50 µV/m (+35 dB)

A star shown against a figure indicates that a higher value of field strength — probably 2 or 3 times the values shown (plus 6 to plus 10 dB) — may be necessary in the presence of high aircraft noise and/or industrial noise.

B.— *Coverage of NDBs (expressed in terms of the radius of a circle, in kilometres, with the NDB at the centre) which may be expected under the assumptions made:*

1) By *day*, over *land*, and for *15 dB S/N ratio* at the boundary of the coverage:

	Input power to antenna			
	(a)	*(b)*	*(c)*	*(d)*
Latitude	*5 kW*	*5 kW*	*1 kW*	*500 W*
5°N – 5°S	320	300	170	120
5° – 15°N&S	510	470	320	250
15° – 25°N&S	>600	600	450	350
25° – 35°N&S	>600★	>600★	600★	500★
>35°N&S	>600★	>600★	>600★	500★

	Input power to antenna			
	(e)	*(f)*	*(g)*	*(h)*
Latitude	*100 W*	*50 W*	*10 W*	*10 W*
5°N – 5°S	50	30	10	<10
5° – 15°N&S	150	90	40	10
15° – 25°N&S	220	160	70	45
25° – 35°N&S	330★	250★	130★	80★
>35°N&S	330★	250★	130★	100★

2) By *night*, over *land*, and for *15 dB S/N ratio* at the boundary of the coverage:

	Input power to antenna			
	(a)	*(b)*	*(c)*	*(d)*
Latitude	*5 kW*	*5 kW*	*1 kW*	*500 W*
5°N – 5°S	190	150	85	50
5° – 15°N&S	210	180	110	70
15° – 25°N&S	320	300	170	120
25° – 35°N&S	390	390	280	200
>35°N&S	390	390	390	310

	Input power to antenna			
	(e)	*(f)*	*(g)*	*(h)*
Latitude	*100 W*	*50 W*	*10 W*	*10 W*
5°N – 5°S	20	<10	<10	<10
5° – 15°N&S	25	15	<10	<10
15° – 25°N&S	50	30	10	<10
25° – 35°N&S	100	70	25	15
>35°N&S	180	120	50	30

6.3.3.1 In all of the above tables, it has to be noted that:

a) the distances are given in kilometres, in accordance with ITU practice;

b) the figures in the final columns, with the heading 10 W, are calculated on the assumption that the low power NDB uses a very inefficient antenna (see 6.3.2, assumption 5 h));

c) a star shown against a figure indicates that the coverage may be limited by aircraft and industrial noises.

6.3.3.2 It has also to be noted that:

a) if a frequency of 200 kHz were used in place of 300 kHz, this would not appreciably affect the coverage of low power short range NDBs, but the coverage of the higher power, longer range beacons (for example, those with a range of 150 km or more) would be increased, as compared with those shown in the tables, by about 20 per cent;

b) if a frequency of 400 kHz were used in place of 300 kHz this would not appreciably affect the coverage of low power short range NDBs, but the coverage of the higher power, longer range beacons (for example, those with a range of 150 km or more) would be decreased, as compared with those shown in the tables, by about 25 per cent;

c) use of an ADF receiver with a narrower band would, other things being equal, provide wider coverage for the same radiated power of the NDB or, for the same coverage, an improved effective signal-to-noise ratio.

For example, if an admittance band of 1 kHz instead of 6 kHz were used, the coverage might be increased by as much as 30 per cent for the same radiated power or, alternatively, the effective signal-to-noise ratio might be increased by as much as 8 dB;

d) if a sector of the coverage of an NDB is over seawater, a greater coverage may be expected within that sector due to:

   1) better ground wave propagation over seawater than over land;

   2) the noise level, which is highest over land, often drops fairly steeply with increasing distance from the land. It might be assumed, therefore, that the distances shown in the tables could be increased by about 30 per cent by day, and by about 20 per cent by night, when the path is over seawater;

e) if, however, the beacon is sited on an island remote from land masses (for example, in mid-Pacific or mid-Atlantic, but not in the Caribbean), the coverage of the beacon is likely to be much greater, particularly in tropical latitudes, than is indicated in the tables; and in such cases figures for coverage similar to those shown for latitudes more than 35°N and S may be assumed for all latitudes, due to the much lower level of atmospheric noise which prevails in mid-ocean as compared with that experienced over, or in proximity to, land masses.

6.3.4 Limitation of coverage of a beacon at night due to “night effect”.

a) The distances, at night, at which the ground wave and sky wave components of the received field are likely to be equal are as follows:

Frequency	*Over land*	*Over sea*
200 kHz	500 km	550 km
300 kHz	390 km	520 km
400 kHz	310 km	500 km

b) The distances, at night, at which the ground wave component of the received field is likely to exceed the sky wave component by 10 dB are as follows:

Frequency	*Over land*	*Over sea*
200 kHz	300 km	320 km
300 kHz	230 km	300 km
400 kHz	200 km	280 km

c) It is, therefore, unlikely that reliable bearings can be obtained, at night, due to interaction of the two components of the received field, at much greater distances than those shown in 6.3.4 b). *These distances are independent of the power of the NDB.*

d) It has to be noted, moreover, that, while with overland paths of good conductivity, night effect will only be serious at somewhat greater distances than those indicated over paths of poor conductivity, night effect may become pronounced at much shorter ranges. This will also depend to some extent upon the characteristics of the radiation system.

6.4 Considerations affecting operations of NDBs

6.4.1 *Depth of modulation*

6.4.1.1 In specifying that the depth of modulation should be maintained as near to 95 per cent as is practicable, it must be noted that, at the frequencies used for NDBs, the small antennas generally in use can affect the effective modulation depth of the NDB system due to attenuation of the sidebands.

6.4.1.2 At this order of frequency, the antennas are normally only a small fraction of a wavelength long; they are therefore highly reactive and tend to have a high Q.

6.4.1.3 The effect is illustrated in Figure C-19, which was compiled from measurements made by one State. The modulating frequency in these measurements was 1 020 Hz. If a lower modulating frequency were used, the effect would be less.

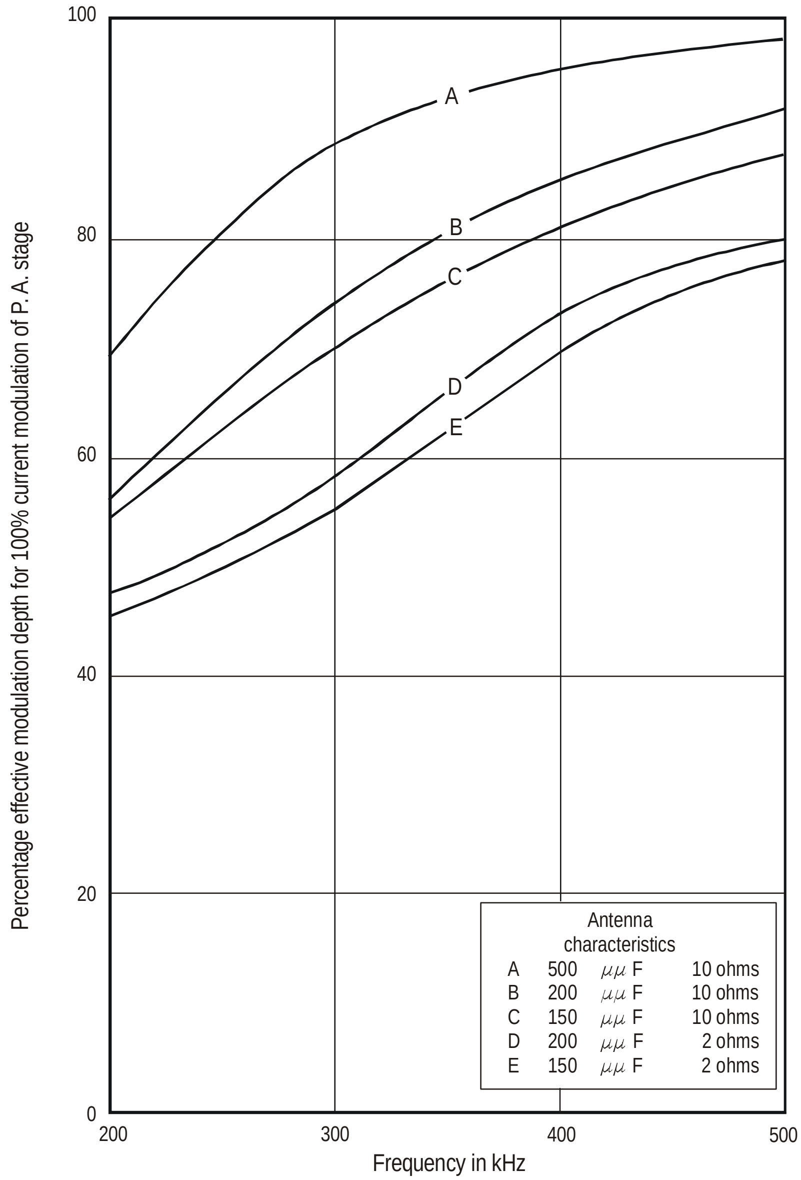
6.4.1.4 In order to reduce the attenuation, attempts should be made to reduce the Q of the antenna. This can be done in two ways, by increasing either its capacity or resistance.

6.4.1.5 Inserting additional resistance in an antenna wastes power, whereas increasing the capacity does not. Additionally, the effect of increasing the capacity is to reduce the voltage across the system and hence to reduce the insulation problems.

6.4.1.6 For these reasons, it is considered desirable to increase antenna capacity by the use of a top load as, for example, in the so-called umbrella top capacity.

6.4.2 *Earth systems*

Frequency planning is done on the assumption that the field strength will be maintained at the correct value. If the earth resistance is high (i.e. an insufficient earth system), not only will the radiation efficiency be low but the power radiated will be sensitive to changes in climatic conditions and other factors affecting the earth loss. In all cases, the earth system needs to be the best possible, taking into account all local circumstances.



Note.— The modulating frequency in these measurements was 1 020 Hz.

Figure C-19. The effect of antenna Q on the depth of modulation of the radiated signal

6.5 Considerations affecting the choice of the modulating frequency for NON/A2A NDBs

Recognition of the fact that modern narrow band ADF receivers have improved selectivity characteristics requires consideration of the fact that, in so far as attenuation of the audio sidebands by these receivers results in a reduction of the effective depth of modulation of the signal, the distance at which satisfactory identification is obtained is consequently reduced. In such circumstances, it is considered that 400 Hz would provide a better identification service than 1 020 Hz. There is some evidence, however, that under conditions of high atmospheric noise, the higher frequency of 1 020 Hz may provide a more easily readable signal.

7. Material concerning DME

7.1 Guidance material concerning both DME/N and DME/P

7.1.1 *System efficiency*

7.1.1.1 System efficiency is the combined effect of down-link garble, ground transponder dead time, up-link garble, and interrogator signal processor efficiency. Since each of these efficiency components are statistically independent, they can be computed individually and then combined to yield the system efficiency. The effect of a single component is defined as the percentage ratio of valid replies processed by the interrogator in response to its own interrogations assuming all other components are not present. The system efficiency is then the product of the individual components.

7.1.1.2 In computing system efficiency, the number of missing replies as well as the accuracy of the range measurement made with the received replies should be considered. Missing replies may result from signal interference due to garble or from interrogations being received at the transponder during a dead time period. Replies which contain significant errors large enough to be rejected by the interrogator signal processing also should be treated as missing replies when computing the efficiency component.

7.1.1.3 The interference rate due to garble is dependent upon the channel assignment plan, traffic loading, and the ground transponder and interrogator receiver bandwidths. Because the FA mode has a wider receiver bandwidth than the IA mode, it is more susceptible to interference. These factors were accommodated in the DME/P system definition and normally do not require special consideration by the operating authority.

7.1.2 *Down-link garble*

Down-link garble occurs when valid interrogations at the ground transponder are interfered with by coincident interrogations from other aircraft and results in loss of signal or errors in time-of-arrival measurement. This undesired air-to-ground loading is a function of the number of interrogating aircraft in the vicinity of the serving transponder and the corresponding distribution of interrogation frequencies and signal amplitudes received at the transponder.

Note.— Transponder to transponder garbling is controlled by the channel assignment authorities.

7.1.3 *Up-link garble*

Up-link garble occurs when valid replies at the interrogator are interfered with by other transponders and results in loss of signal or errors in pulse time-of-arrival measurement. The garble can be interference from any transponder whose frequency is within the bandwidth of the interrogator, including those on the same frequency, but with different pulse coding. This undesired ground-to-air loading is a function of the number of transponders in the vicinity of the interrogator and the corresponding distribution of reply frequencies and signal amplitudes received at the interrogator.

7.1.4 *Interrogator processor efficiency*

The interrogator signal processor efficiency is the ratio of the number of replies processed by the interrogator to the number of interrogations in the absence of garble and transponder dead time effects. This efficiency depends on the reply pulse threshold level and the receiver noise level.

7.1.5 *Relationship between aircraft served and transmission rate*

7.1.5.1 Specification of the maximum transponder transmission rate establishes the maximum average transmitter power level. Chapter 3, 3.5.4.1.5.5 recommends that the transponder have a transmission rate capability of 2 700 pulse pairs per second if 100 aircraft are to be served. This represents typical transponder loading arising from 100 aircraft. To determine the actual transmission rate capability that should be accommodated at a given facility during peak traffic conditions requires that the maximum number of interrogators be estimated. To compute the interrogation loading on the transponder, the following should be considered:

a) the number of aircraft that constitutes the peak traffic load;

b) the number of interrogators in use on each aircraft;

c) the distribution of operating modes of the interrogators in use (e.g. search, initial approach, final approach, ground test);

d) the appropriate pulse repetition frequency as given in Chapter 3, 3.5.3.4.

7.1.5.2 Given the interrogation loading which results from the peak traffic as well as the reply efficiency of the transponder in the presence of this load, the resulting reply rate can be computed, thereby establishing the required transmitter capability. This reply rate is the level that, when exceeded, results in a reduction in receiver sensitivity (as specified in Chapter 3, 3.5.4.2.4) in order to maintain the reply rate at or below this maximum level.

7.1.6 *Siting of DME associated with ILS or MLS*

7.1.6.1 The DME should, where possible, provide to the pilot an indicated zero range at touchdown in order to satisfy current operational requirements.

7.1.6.2 The optimum site for a DME transponder is dependent upon a number of technical and operational factors. DME/N may be installed with ILS or MLS where operational requirements permit. DME/P, which provides higher accuracy and coverage throughout the entire runway region, is required to support the more flexible and advanced operations that are available with MLS.

7.1.6.3 In the case of DME/N, the provision of zero range indication may be achieved by siting the transponder as close as possible to the point at which zero range indication is required. Alternatively, the transponder time delay can be adjusted to permit aircraft interrogators to indicate zero range at a specified distance from the DME antenna. When the indicated DME zero range has a reference other than the DME antenna, consideration should be given to publishing this information.

7.1.6.4 In the case of DME/P, in order to meet accuracy and coverage requirements, particularly in the runway region, it is recommended that the DME/P be sited as closely as possible to the MLS azimuth facility, consistent with obstacle clearance criteria. For aircraft equipped with a full MLS capability, the desired zero range indication can then be obtained by utilizing MLS basic data. Note that the DME/P transponder time delay must not be adjusted for this purpose.

7.1.6.5 It is desirable that all users obtain indicated zero range at touchdown irrespective of the airborne equipment fitted. This would necessitate location of the DME/P abeam the runway at the touchdown point. In this case accuracy requirements for DME/P would not be met on the runway. It must be noted that MLS Basic Data Word 3 only permits the coding of DME/P coordinates within certain limits.

7.1.6.6 If an MLS/DME/P and an ILS/DME/N serve the same runway, an aircraft equipped with a minimum MLS capability can have a zero range indication at the MLS approach azimuth site when operating on MLS and a zero range indication at the touchdown point when operating on ILS. As this is considered to be operationally unacceptable, specifically from an ATC point of view, and if ILS/MLS/DME frequency tripling to prevent the relocation of the DME/N is not possible, the implementation of DME/P is to be postponed until the DME/N is withdrawn.

7.1.6.7 The nominal location of the zero range indication provided by a DME/N interrogator needs to be published.

7.1.6.8 In considering DME sites, it is also necessary to take into account technical factors such as runway length, profile, local terrain and transponder antenna height to assure adequate signal levels in the vicinity of the threshold and along the runway, and also to assure the required coverage volume (circular or sector). Care is also to be taken that where distance information is required in the runway region, the selected site is not likely to cause the interrogator to lose track due to excessive rate of change of velocity (i.e. the lateral offset of the DME antenna must be chosen with care).

7.1.7 *Geographical separation criteria*

7.1.7.1 In order to allow consideration of actual antenna designs, equipment characteristics, and service volumes, the signal ratios needed to assure interference-free operation of the various facilities operating on DME channels are provided in 7.1.8 and 7.1.9. Given these ratios, the geographical separations of facilities may be readily evaluated by accounting for power losses over the propagation paths.

7.1.8 *Desired to undesired (D/U) signal ratios at the airborne receiver*

7.1.8.1 Table C-4 indicates the necessary D/U signal ratios needed to protect the desired transponder reply signal at an airborne receiver from the various co-frequency/adjacent frequency, same code/different code, undesired transponder reply signal combinations that may exist. The prerequisite for any calculation using the provided ratios is that the required minimum power density of the desired DME is met throughout the operationally published coverage volume. For initial assignments, the D/U ratios necessary to protect airborne equipment with 6-microsecond decoder rejection should be used. In making an assignment, each facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made.

7.1.8.2 Accordingly, DME channel assignments depend upon the following:

a) *For co-channel assignments:* This condition occurs when both the desired and undesired signals operate on a channel (W, X, Y or Z) that is co-frequency, same code. The D/U signal ratio should be at least 8 dB throughout the service volume.

b) *For co-frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel. A similar Y channel and a Z channel combination also applies.

c) *For first adjacent frequency, same code assignments:* This condition occurs when both the desired and undesired facilities are of W, X, Y or Z type.

d) *For first adjacent frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel, but with a frequency offset of 1 MHz between transponder reply frequencies. A similar Y channel and a Z channel combination also applies.

Table C-4. Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency:		
Same pulse code	8	8
Different pulse code	8	–42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	–42
Different pulse code	$-(P_u + 7)$	–75
Second adjacent frequency:		
Same pulse code	$-(P_u + 19)$	–75
Different pulse code	$-(P_u + 27)$	–75

Note 1.— The D/U ratios in column A protect those DME/N interrogators operating on X or Y channels. Column A applies to decoder rejection of 6 microseconds.

Note 2.— The D/U ratios in column B protect those DME/N or DME/P interrogators utilizing discrimination in conformance with 3.5.5.3.4.2 and 3.5.5.3.4.3 of Chapter 3 and providing a decoder rejection conforming to 3.5.5.3.5 of Chapter 3.

Note 3.— P_u is the peak effective radiated power of the undesired signal in dBW.

Note 4.— The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the EIRP of the undesired facility.

Note 5.— In assessing adjacent channel protection, the magnitude of D/U ratio in column A should not exceed the magnitude of the value in column B.

e) *For second adjacent frequency, same or different code assignments:* The second adjacent frequency combinations generally need not be frequency protected. However, special attention should be given to Note 4 of Table C-4, especially if the undesired facility is a DME/P transponder.

7.1.9 *Special considerations for DME Y and Z channel assignments*

The channel assignment plan for DME is such that the transponder reply frequency for each Y or Z channel is the same as the interrogation frequency of another DME channel. Where the reply frequency of one DME matches the interrogation frequency of a second DME, the two transponders should be separated by a distance greater than the radio horizon distance between them. The radio horizon distance is calculated taking into account the elevations of the two transponder antennas.

7.1.10 *Special considerations for DME/P associated with ILS*

7.1.10.1 For those runways where it is intended to install DME associated with ILS and where early MLS/RNAV operations are planned, installation of DME/P is preferred.

7.1.10.2 When it is intended to use the DME/P ranging information throughout the terminal area, interrogation pulse pairs with the correct spacing and nominal frequency must trigger the transponder if the peak power density at the transponder antenna is at least minus 93 dBW/m^2. This sensitivity level is based on the values contained in Chapter 3, 3.5.4.2.3.1

and it is applied to DME/P IA mode, where at this level DME/P IA mode is intended to comply with DME/N reply efficiency and at least DME/N accuracy.

7.1.11 *Considerations for the universal access transceiver (UAT)*

7.1.11.1 Frequency planning criteria to ensure compatibility between DME and the UAT are contained in Part II of the *Manual on the Universal Access Transceiver (UAT)* (Doc 9861).

7.2 Guidance material concerning DME/N only

7.2.1 *Coverage of DME/N*

7.2.1.1 Whether a particular installation can provide the required frequency, protected coverage volume can be determined by using Figure C-20. The propagation loss for paths without obstructions uses the IF-77 propagation model.

7.2.1.2 Whenever a DME that provides coverage using either a directional or bi-directional DME antenna, the antenna pattern in azimuth and elevation has to be taken into account to achieve the full benefit of the reduced separation requirements outside the antennas main lobe. The actual radiation patterns of the antennas depend on a number of factors, including height of the antenna phase centre, height of the DME counterpoise above ground level (AGL), terrain surface roughness, terrain form, site elevation above mean sea level (MSL), and conductivity of ground and counterpoise. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the equivalent isotropically radiated power (EIRP). Conversely, practical experience has shown, that under favourable siting conditions, and under the less pessimistic conditions often found in actual service, satisfactory system operation is achieved with a lower EIRP. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, the values in Figure C-20 are recommended.

Note.— Further guidance may be found in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (*Doc 9718).*

7.2.2 *EIRP of DME/N facilities*

7.2.2.1 The power density figure prescribed in Chapter 3, 3.5.4.1.5.2 is based on the following example:

Airborne receiver sensitivity	–120 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+9 dB
Power required at antenna	–111 dBW

Minus 111 dBW at the antenna corresponds to minus 89 dBW/ m^2 at the mid-band frequency.

7.2.2.2 Nominal values of the necessary EIRP to achieve a power density of minus 89 dBW/m^2 are given in Figure C-20. For coverage under difficult terrain and siting conditions it may be necessary to make appropriate increases in the EIRP. Conversely, under favourable siting conditions, the stated power density may be achieved with a lower EIRP.

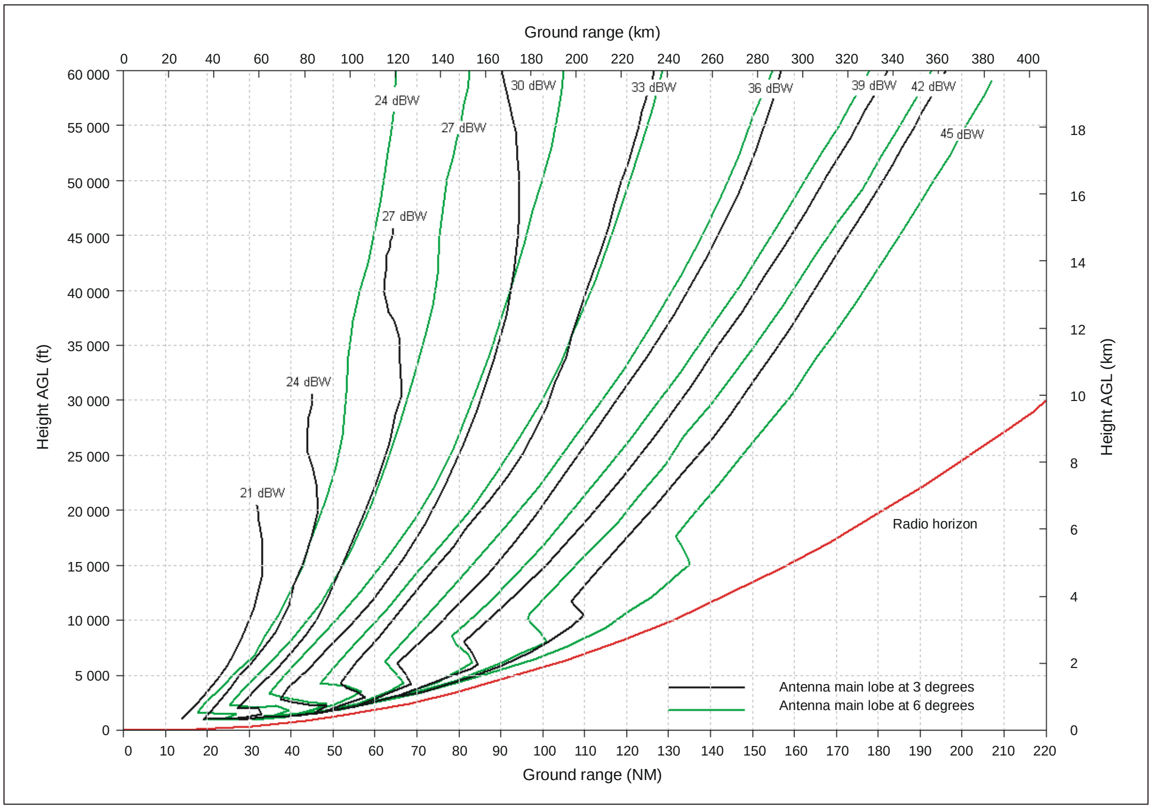


Figure C-20. Necessary EIRP to achieve a power density of –89 dBW/m^2 as a function of height above and distance from the DME

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.

Note 2.— The radio horizon in Figure C-20 is for a DME antenna located 5 m (17 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— If the antenna is located significantly higher than the assumed reference antenna, the radio horizon and power density will increase.

7.2.3 *DME-DME RNAV*

7.2.3.1 There is an increasing use of DME to support area navigation (RNAV) operations. Although the use of DME to support RNAV operations does not impose any additional technical requirements on the DME system, it does raise some additional issues compared with the traditional use of DME with VOR to support conventional operations. These are examined briefly below.

7.2.3.2 DME/DME positioning is based on the aircraft RNAV system triangulating position from multiple DME ranges from DME facility locations in the aircraft database. The resulting accuracy of the position solution depends on the range to the DMEs and their relative geometry. Some additional measures are therefore necessary to ensure that the DME infrastructure is adequate to support the RNAV operation, i.e. that sufficient DMEs are available and that their location provides adequate geometry to meet the accuracy requirements. For approach and departure procedures, it is also necessary to confirm that there is adequate signal strength and that there are no false locks or unlocks due to multipath. When ensuring there are sufficient DMEs, it is also important to identify any critical DMEs (i.e. those which must be operational for the necessary performance to be assured).

7.2.3.3 Errors in published DME facility locations will result in RNAV position errors. It is therefore important that DME positions are correctly surveyed and that adequate procedures are in place to ensure that the location data are correctly published. For DME facilities collocated with VOR, the DME position should be separately surveyed and published if the separation distance exceeds 30 m (100 ft).

Note.— Standards for data quality and publication of DME location information are given in Annex 15 — Aeronautical Information Services*.*

7.2.3.4 When using DME to support RNAV, scanning DME aircraft receivers usually do not check the DME identification. As a consequence, removing the identification of a DME during tests and maintenance operations does not guarantee that the signals will not be used operationally. Maintenance actions that may provide misleading information should be minimized.

Note 1.— Further guidance on flight inspection of DME-DME RNAV procedures is given in Doc 8071.

Note 2.— Further guidance on navigation infrastructure assessment to support RNAV procedures is given in EUROCONTROL-GUID-0114 *(available at http://www.eurocontrol.int/eatm /public/standard_page/gr_lib.html) and on the performance-based navigation (PBN) page of the ICAO website at http://www.icao.int/pbn.*

7.3 Guidance material concerning DME/P only

7.3.1 *DME/P system description*

7.3.1.1 The DME/P is an integral element of the microwave landing system described in Chapter 3, 3.11. The DME/P signal format defines two operating modes, initial approach (IA) and final approach (FA). The IA mode is compatible and interoperable with DME/N and is designed to provide improved accuracies for the initial stages of approach and landing. The FA mode provides substantially improved accuracy in the final approach area. Both modes are combined into a single DME/P ground facility and the system characteristics are such that DME/N and DME/P functions can be combined in a single interrogator. The IA and FA modes are identified by pulse codes which are specified in Chapter 3, 3.5.4.4. In the MLS approach sector, the DME/P coverage is at least 41 km (22 NM) from the ground transponder. It is intended that the interrogator does not operate in the FA mode at ranges greater than 13 km (7 NM) from the transponder site, although the transition from the IA mode may begin at 15 km (8 NM) from the transponder. These figures were selected on the assumption that the transponder is installed beyond the stop end of the runway at a distance of approximately 3 600 m (2 NM) from the threshold.

7.3.1.2 A major potential cause of accuracy degradation encountered in the final phases of the approach and landing operation is multipath (signal reflection) interference. DME/P FA mode minimizes these effects by using wideband signal processing of pulses having fast rise time leading edges, and by measuring the time of arrival at a low point on the received pulse where it has not been significantly corrupted by multipath. This is in contrast to the slower rise time pulses and higher thresholding at the 50 per cent level used in DME/N.

7.3.1.3 Because the FA mode is used at ranges less than 13 km (7 NM), the transmitter can provide an adequate signal level to meet the required accuracy without the fast rise time pulse violating the transponder pulse spectrum requirements. Use of the 50 per cent threshold and a narrow receiver bandwidth in the IA mode permits an adequate but less demanding performance to the coverage limits. The transponder determines the interrogation mode in use by the interrogation code in order to time the reply delay from the proper measurement reference. The IA mode is interoperable with DME/N permitting a DME/N interrogator to be used with a DME/P transponder to obtain at least the accuracy with a DME/N transponder. Similarly, a DME/P interrogator may be used with a DME/N transponder.

7.3.2 *DME/P system accuracy requirements*

7.3.2.1 *DME/P accuracy requirements*

7.3.2.1.1 When considering the DME/P accuracy requirement, the operations that can be performed in the service volume of the final approach mode tend to fall into one of two groups. This has led to two accuracy standards being defined for the final approach mode:

a) *accuracy standard 1:* this is the least demanding and is designed to cater for most CTOL operations;

b) *accuracy standard 2:* this gives improved accuracy that may be necessary for VTOL and STOL operations, CTOL flare manoeuvres using MLS flare elevation guidance and CTOL high-speed turnoffs.

7.3.2.1.2 Table C-5 shows applications of DME and typical accuracy requirements. This will assist in selecting the appropriate accuracy standard to meet the operational requirement. The calculations are based on a distance of 1 768 m (5 800 ft) between the DME antenna and the runway threshold. The following paragraphs refer to Table C-5.

7.3.2.1.3 It is intended that the DME/P accuracy approximately corresponds to the azimuth function PFE at a distance of 37 km (20 NM) from the MLS reference datum both along the extended runway centre line and at an azimuth angle of 40 degrees. The CMN is the linear equivalent of the plus or minus 0.1 degree CMN specified for the azimuth angle function.

7.3.2.1.4 PFE corresponds to azimuth angular error; CMN is approximately the linear equivalent of the plus or minus 0.1 degree CMN specified for the azimuth angle system.

7.3.2.1.5 The plus or minus 30 m (100 ft) PFE corresponds to a plus or minus 1.5 m (5 ft) vertical error for a 3-degree elevation angle.

7.3.2.1.6 Flare initiation begins in the vicinity of the MLS approach reference datum; MLS elevation and DME/P provide vertical guidance for automatic landing when the terrain in front of the runway threshold is uneven.

7.3.2.1.7 Sensitivity modification or autopilot gain scheduling requirements are not strongly dependent on accuracy.

Table C-5.

Function	Typical distance from the threshold	PFE (95% probability)	CMN (95% probability)
Approach (7.3.2.1.3)			
— extended runway centre line	37 km (20 NM)	±250 m (±820 ft)	±68 m (±223 ft)
— at 40° azimuth	37 km (20 NM)	±375 m (±1 230 ft)	±68 m (±223 ft)
Approach (7.3.2.1.4)			
— extended runway centre line	9 km (5 NM)	±85 m (±279 ft)	±34 m (±111 ft)
— at 40° azimuth	9 km (5 NM)	±127 m (±417 ft)	±34 m (±111 ft)
Marker replacement			
— outer marker	9 km (5 NM)	±800 m (±2 625 ft)	not applicable
— middle marker	1 060 m (0.57 NM)	±400 m (±1 312 ft)	not applicable

Function	Typical distance from the threshold	PFE (95% probability)	CMN (95% probability)
30 m decision height determination (100 ft) (7.3.2.1.5)			
— 3° glide path (CTOL)	556 m (0.3 NM)	±30 m (±100 ft)	not applicable
— 6° glide path (STOL)	556 m (0.3 NM)	±15 m (±50 ft)	not applicable
Flare initiation over uneven terrain (7.3.2.1.6)			
— 3° glide path (CTOL)	0	±30 m (±100 ft)	±18 m (±60 ft)
— 6° glide path (STOL)	0	±12 m (±40 ft)	±12 m (±40 ft)
Sensitivity modifications (7.3.2.1.7) (autopilot gain scheduling)	37 km (20 NM) to 0	±250 m (±820 ft)	not applicable
Flare manoeuvre with MLS flare elevation (7.3.2.1.8)			
— CTOL	0	±30 m (±100 ft)	±12 m (±40 ft)
— STOL	0	±12 m (±40 ft)	±12 m (±40 ft)
Long flare alert (7.3.2.1.9)	Runway region	±30 m (±100 ft)	not applicable
CTOL high speed roll-out/turnoffs (7.3.2.1.10)	Runway region	±12 m (±40 ft)	±30 m (±100 ft)
Departure climb and missed approach	0 to 9 km (5 NM)	±100 m (±328 ft)	±68 m (±223 ft)
VTOL approaches (7.3.2.1.11)	925 m (0.5 NM) to 0	±12 m (±40 ft)	±12 m (±40 ft)
Coordinate translations (7.3.2.1.12)	—	±12 m to ±30 m (±40 ft to ±100 ft)	±12 m (±40 ft)

7.3.2.1.8 It is intended that this specification applies when vertical guidance and sink rate for automatic landing are derived from the MLS flare elevation and the DME/P.

Note.— Although the standard has been developed to provide for MLS flare elevation function, this function is not implemented and is not intended for future implementation.

7.3.2.1.9 It indicates to the pilot if the aircraft is landing beyond the touchdown region.

7.3.2.1.10 The roll-out accuracy requirement reflects system growth potential. In this application the roll-out PFE would be dictated by the possible need to optimize roll-out deceleration and turnoff so as to decrease runway utilization time.

7.3.2.1.11 It is intended to assure the pilot that the aircraft is over the landing pad before descending.

7.3.2.1.12 It may be desirable to translate the MLS coordinates from one origin to another when the antennas are not installed in accordance with Chapter 3, 3.11.5.2.6 or 3.11.5.3.5. The figures in the table are typical of a VTOL application; actual values will depend on the geometry of the installation.

7.3.3 *DME/P error budgets*

Example error budgets for DME/P accuracy standards 1 and 2 are shown in Table C-6. If the specified error components are not individually exceeded in practice, it can be expected that the overall system performance, as specified in Chapter 3, 3.5.3.1.4, will be achieved. A garbling contribution to the system error is computed by taking the root sum square (RSS) of the errors obtained in the specified down-link environment with those obtained in the specified up-link environment and removing, on an RSS basis, the error obtained in a non-garbling environment.

Table C-6. Example of DME/P error budget

Error source	Error component	FA mode Standard 1 PFE m (ft)	FA mode Standard 1 CMN m (ft)	FA mode Standard 2 PFE m (ft)	FA mode Standard 2 CMN m (ft)	IA mode PFE m (ft)	IA mode CMN m (ft)
Instrumentation	Transponder	±10 (±33)	±8 (±26)	±5 (±16)	±5 (±16)	±15 (±50)	±10 (±33)
	Interrogator	±15 (±50)	±10 (±33)	±7 (±23)	±7 (±23)	±30 (±100)	±15 (±50)
Site related	Down-link specular multipath	±10 (±33)	±8 (±26)	±3 (±10)	±3 (±10)	±37 (±121)	±20 (±66)
	Up-link specular multipath	±10 (±33)	±8 (±26)	±3 (±10)	±3 (±10)	±37 (±121)	±20 (±66)
	Non-specular (diffuse) multipath	±3 (±10)	±3 (±10)	±3 (±10)	±3 (±10)	±3 (±10)	±3 (±10)
	Garble	±6 (±20)	±6 (±20)	±6 (±20)	±6 (±20)	±6 (±20)	±6 (±20)

Note 1.— The figures for "non-specular multipath" and for "garble" are the totals of the up-link and down-link components.

Note 2.— PFE contains both bias and time varying components. In the above table the time varying components and most site related errors are assumed to be essentially statistically independent. The bias components may not conform to any particular statistical distribution.

In considering these error budgets, caution is to be exercised when combining the individual components in any particular mathematical manner.

Note 3.— The transmitter wave form is assumed to have a 1 200 nanosecond rise time.

7.3.4 *System implementation*

7.3.4.1 While the DME/P may be implemented in various ways, the instrumental and propagation errors assumed are typical of those obtainable with equipment designs which provide internal time delay drift compensation and which establish timing reference points by thresholding on the leading edge of the first pulse of a pulse pair using the following techniques:

a) *IA mode.* A conventional technique which thresholds at the 50 per cent amplitude point;

b) *FA mode.* A delay-attenuate-and-compare (DAC) technique which thresholds between the 5 per cent and 30 per cent amplitude points.

7.3.4.2 Accuracy standard 1 can be achieved using a delay of 100 nanoseconds and an attenuation of 5 to 6 dB. It is also required that the threshold amplitude point of both the delayed pulse and the attenuated pulse lie within the partial rise time region.

7.3.4.3 The example above does not preclude time of arrival measurement techniques other than the DAC from being used, but it is necessary in any case that threshold measurements take place during the pulse partial rise time.

7.3.5 *DME/P interrogator signal processing*

7.3.5.1 *During acquisition*

a) The interrogator acquires and validates the signal within 2 seconds before transitioning to track mode even in the presence of squitter and random pulse pairs from adjacent channels, which result in a 50 per cent system efficiency.

b) After loss of the acquired signal in either the IA or FA mode, the interrogator provides a warning output within 1 second, during which time the guidance information continues to be displayed. After loss of signal, the interrogator returns to the search condition in the IA mode in order to re-establish track.

7.3.5.2 *During track*

When track is established, the receiver output consists of valid guidance information before removing the warning. The validation process continues to operate as long as the interrogator is in track. The interrogator remains in track as long as the system efficiency is 50 per cent or greater. While in track, the receiver provides protection against short duration, large amplitude erroneous signals.

7.3.5.3 *Range date filter*

The accuracy specifications in Chapter 3, 3.5.3.1.4, as well as the error budgets discussed in 7.3.3, assume that the higher frequency noise contributions are limited by a low pass filter with a corner frequency of qw as specified in Figure C-21. Depending upon the user's application, additional filtering for noise reduction can be used provided that the induced phase delay and amplitude variation do not adversely affect the aircraft flight control system's dynamic response. The following sections recommend additional features which should be incorporated into the data filter.

7.3.5.4 *Velocity memory*

The data filter may require a velocity memory in order to achieve the specified accuracies in Chapter 3, 3.5.3.1.4 with a system efficiency of 50 per cent. It should be noted that low system efficiencies can occur in the IA mode during identification transmissions.

7.3.5.5 *Outlier rejection*

Range estimates which are significantly different from previous filtered range estimates, because they cannot be the result of aircraft motion, should be assumed to be in error. Such data should be rejected at the input to the data filter.

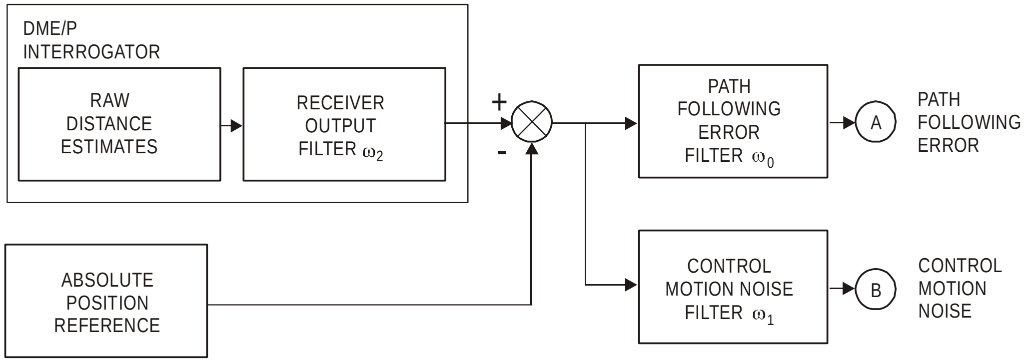
7.3.6 *DME/P error measurement methods*

7.3.6.1 *System errors*

7.3.6.1.1 The DME/P system accuracies are specified in Chapter 3, 3.5.4.1.4 in terms of path following error (PFE) and control motion noise (CMN). These parameters describe the interaction of the DME/P guidance signal with the aircraft in terms directly related to aircraft position errors and flight control system design.

7.3.6.1.2 For the purposes of determining compliance with the accuracy standard, the PFE and CMN components are evaluated over any T second interval (where T = 40 seconds in the IA mode and 10 seconds in the FA mode) of the flight error record taken within the DME/P coverage limits. The 95 per cent probability requirement is interpreted to be satisfied if the PFE and CMN components do not exceed the specified error limits for a total period that is more than 5 per cent of the evaluation time interval. This is illustrated in Figure C-21. To evaluate the PFE and CMN components of the DME/P guidance data, the true aircraft position, as determined by a suitable position reference, is subtracted from the guidance data to form an error signal. This error signal is then filtered by the PFE and CMN filters, where the outputs provide suitable estimates of the PFE and CMN components, respectively. These filters are defined in Figure C-21.

7.3.6.1.3 These filters can be utilized to determine the transponder instrumentation error components specified in Chapter 3, 3.5.4.5.3 and 3.5.4.5.4. Similarly, the interrogator instrumentation error components, specified in Chapter 3, 3.5.5.4, can be determined.



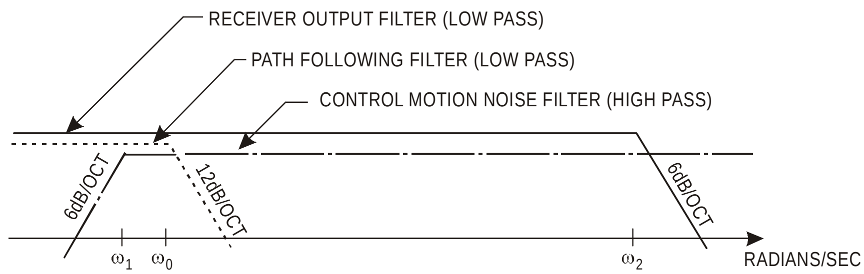
GUIDANCE FUNCTION	CORNER FREQUENCIES (RADIANS/SEC)		
	ω_0	ω_1	ω_2*
DME/P	1.5	0.5	10

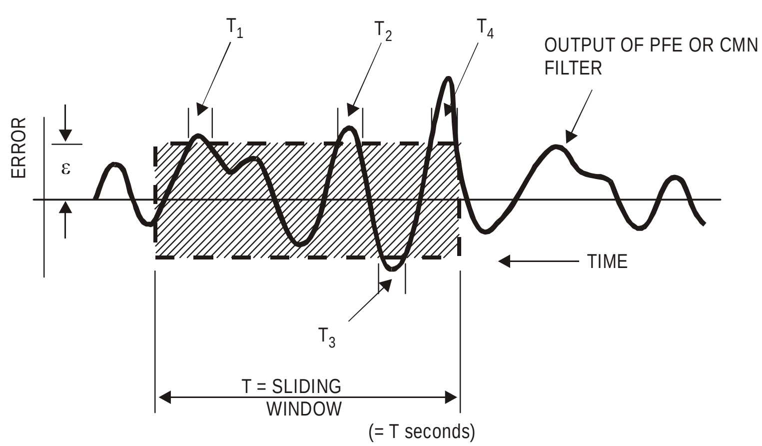
* This corner frequency may be less than 10 rad/sec for some applications.

RECEIVER OUTPUT FILTER $\dfrac{\omega_2}{S + \omega_2}$

PATH FOLLOWING FILTER $\dfrac{\omega_n^2}{S^2 + 2\zeta\,\omega_n S + \omega_n^2}$ $\zeta = 1; \omega_0 = .64\,\omega_n$

CONTROL MOTION NOISE FILTER $\dfrac{S}{S + \omega_1}$





	IA MODE	FA MODE
T	40 sec	10 sec

DME/P measurement methodology: ε is the error specification; T region to be evaluated; T_1, T_2, T_3 ... time intervals that error exceeds specifications. For the equipment to be acceptable in this region, the following inequality should be true:

$(T_1 + T_2 + T_3 + ...) / T \leq 0.05$.

Figure C-21

7.3.7 *Multipath effects*

7.3.7.1 Under the multipath conditions likely to exist, the accuracy specifications of the DME/P assume that the performance is not degraded beyond a certain limit and that this degradation is equally applied to both interrogator and transponder receiver.

7.3.7.2 To ensure that the equipment is working according to the specifications, the following should apply to FA mode operation of the system:

a) if a signal of sufficient power to make thermal noise contributions insignificant is applied to the receivers, a second signal delayed between 0 and 350 nanoseconds with respect to the first, with an amplitude 3 dB or more below the first and with a scalloping frequency between 0.05 and 200 Hz should not produce errors in the receiver output of more than plus or minus 100 nanoseconds (15 m);

b) for delays more than 350 nanoseconds the error contribution will be reduced considerably. A typical value will be plus or minus 7 nanoseconds (1 m).

7.3.7.3 The airborne DME antenna should be located so as to preclude antenna gain reductions in the forward direction with the aircraft in the landing configuration. Any such antenna gain reductions could enhance the multipath error component when the aircraft is on approach and landing phases when highest DME accuracies are required.

7.3.8 *DME/P power budget*

7.3.8.1 Tables C-7 and C-8 are an example of CTOL air-to-ground and ground-to-air power budgets. The permitted peak ERP value is based on a pulse shape which meets the spectral constraints in Chapter 3, 3.5.4.1.3 e).

Table C-7. CTOL ground-to-air power budget

Power budget items	41 km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Peak effective radiated power, dBm	55	55	55	55
Ground multipath loss, dB	–5	–3	–4	–17
Antenna pattern loss, dB	–4	–2	–5	–5
Path loss, dB	–125	–115	–107	–103
Monitor loss, dB	–1	–1	–1	–1
Polarization and rain loss, dB	–1	–1	0	0
Received signal at aircraft, dBm	–81	–67	–62	–71
Power density at aircraft, dBW/m^2	–89	–75	–70	–79
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	–4	–4	–4	–4
Received signal at interrogator, dBm	–85	–71	–66	–75
Receiver noise video, dBm				
(Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		–103	–103	–103
IF BW: 0.8 MHz	–109			
Signal-to-noise ratio (video), dB	24	32	37	28

Table C-8. CTOL air-to-ground power budget

Power budget items	41 km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Interrogator transmitter power, dBm	57	57	57	57
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	–4	–4	–4	–4
Peak effective radiated power, dBm	53	53	53	53
Ground multipath loss, dB	–5	–3	–4	–17
Path loss, dB	–125	–115	–107	–103
Polarization and rain loss, dB	–1	–1	0	0
Received signal at transponder antenna, dBm	–78	–66	–58	–67
Ground antenna gain, dB	8	8	8	8
Pattern loss, dB	–4	–2	–5	–5
Cable loss, dB	–3	–3	–3	–3
Received signal at transponder, dBm	–77	–63	–58	–67
Receiver noise video, dBm				
(Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		–106	–106	–106
IF BW: 0.8 MHz	–112			
Signal-to-noise ratio (video), dB	35	43	48	39

7.3.8.2 In the power budget calculations, it is assumed that the aircraft antenna is not shielded by the aircraft structure including the landing gear when extended.

7.3.8.3 The video power signal-to-noise ratio is related to the IF power signal-to-noise ratio in the following manner:

$$\text{S/N (video)} = \text{S/N (IF)} + 10 \log \frac{\text{IF noise bandwidth}}{\text{video noise bandwidth}}$$

Note 1.— The distances are measured from the transponder antenna.

Note 2.— Frequency dependent parameters were calculated for 1 088 MHz.

7.3.9 *DME/P monitor time delay measurement*

The required time delay measurement can be accomplished by measuring the output of a PFE filter and making a control decision within 1 second. However, since the transponder PFE is a slowly varying error component, an equivalent measurement is to average the unfiltered time delay samples for 1 second.

8. Material concerning power supply switch-over times

8.1 Power supply switch-over times for ground-based radio aids used in the vicinity of aerodromes

The power supply switch-over times for radio navigation aids and ground elements of communications systems are dependent on the type of runway and aircraft operations to be supported. Table C-9 indicates representative switch-over times which may be met by power supply systems currently available.

Table C-9. Power supply switch-over times for ground-based radio aids used at aerodromes

Type of runway	Aids requiring power	Maximum switch-over times (seconds)
Instrument approach	SRE	15
	VOR	15
	NDB	15
	D/F facility	15
Precision approach, Category I	ILS localizer	10
	ILS glide path	10
	ILS middle marker	10
	ILS outer marker	10
	PAR	10
Precision approach, Category II	ILS localizer	0
	ILS glide path	0
	ILS inner marker	1
	ILS middle marker	1
	ILS outer marker	10
Precision approach, Category III	(same as Category II)	

$$\text{Power into isotropic antenna (dBm)} = \text{Power density (dBW/m}^2\text{)} - 5.5$$

2.6.2.2 The angle function measurement assumes a 26-kHz beam envelope filter bandwidth. The video (SNR) given in 2.6.1 is related to the intermediate frequency (IF) SNR by:

$$\text{SNR (Video)} = \text{SNR (IF)} + 10\log\left[\frac{\text{IF noise bandwidth}}{\text{Video noise bandwidth}}\right]$$

2.6.2.3 The DPSK preamble function analysis assumes: 1) a carrier reconstruction phase lock loop airborne receiver implementation; and 2) that the receiver preamble decoder rejects all preambles which do not satisfy the Barker code or fail the preamble parity check.

2.6.2.4 Items a) through e) in Table G-1 are functions of the aircraft position or weather, and thus have been assumed to be random events. That is, they will simultaneously reach their worst-case values only on rare occasions. Therefore, these losses are viewed as random variables and are root-sum-squared to obtain the loss component.

2.6.2.5 To support autoland operations, power densities higher than those specified for the approach azimuth angle signals in Chapter 3, 3.11.4.10.1 are required at the lower coverage limit above the runway surface to limit the CMN to 0.04 degree. Normally, this additional power density will exist as a natural consequence of using the same transmitter to provide the scanning beam and DPSK signals and considering other power margins such as the available aircraft antenna gain, propagation losses, coverage losses at wide angles and rain losses which can be, at least partially, discounted in the runway region (see Table G-1).

2.6.3 *Multipath relative power density*

2.6.3.1 Fixed or mobile obstacles around the MLS ground transmitting antennas may create reflections which are known as multipath. The reflections are affecting all MLS transmissions (DPSK, angle guidance signals, out-of-coverage indication signals and clearance pulses). Relative levels between the direct guidance signal (coding the correct guidance signal) and the reflected signals are used by the MLS angular receiver to acquire and track the correct signals. These relative levels therefore have to be within given and known tolerances to allow correct receiver performances. The MOPS for MLS Airborne Receiving Equipment, EUROCAE ED-36B document, contains the MLS receivers' minimum operational performance specifications ensuring correct performances against the multipath environment, as specified in Chapter 3, 3.11.4.10.3.

2.6.3.2 The four-decibel minimum ratio in Chapter 3, 3.11.4.10.3.1 and 3.11.4.10.3.3, guarantees a valid acquisition by the receiver. Lower ratios may delay signal acquisition or create false acquisition and tracking of multipath signals.

2.6.3.3 The maximum one-second duration in Chapter 3, 3.11.4.10.3.1 and 3.11.4.10.3.3, will ensure that the correct guidance information will continue to be output by the receiver without alert and will therefore not cause loss of service. This duration has to be assessed using approaching aircraft minimum ground speed.

2.6.3.4 Accuracy requirements will limit the level and duration of azimuth multipath coding angles within a narrow sector around centreline (i.e. +/-4°) as the scanning beam shape depicted in Chapter 3, 3.11.5.2.1.3, will be affected. The periodic ground and flight checks will show whether the error contribution from static multipath is compatible with the accuracy requirements. Critical and sensitive areas protection procedures will ensure that dynamic multipath error contribution will not degrade the overall accuracy beyond accuracy requirements.

2.6.3.5 For elevation guidance, signal-in-space degradation by multipath at lower height is not anticipated.

2.6.4 *Airborne power budget*

2.6.4.1 Table G-2 provides an example of an airborne power budget used in developing the power density standards.

2.7 Data applications

2.7.1 *Basic data.* The basic data defined in Chapter 3, 3.11.4.8.2.1 are provided to enable airborne receivers to process scanning beam information for various ground equipment configurations and to adjust outputs so they are meaningful to the pilot or airborne system. Data functions are also used to provide additional information (e.g. station identification and equipment status) to the pilot or airborne system.

2.7.2 *Auxiliary data*

2.7.2.1 The auxiliary data defined in Chapter 3, 3.11.4.8.3.1 and 3.11.4.8.3.2 are provided to digitally uplink the following types of information:

a) *Data describing ground equipment siting geometry.* These are transmitted in words A1-A4 and in some of the words B40-B54.

b) *Data to support MLS/RNAV operations.* These are transmitted in words B1-B39.

c) *Operational information data.* These are transmitted in words B55-B64.

2.7.2.2 The rates of transmission of auxiliary data words are based on the following criteria:

a) Data that are required to be decoded within six seconds upon entering the MLS coverage volume should be transmitted with a maximum time between transmissions of 1 second (see 7.3.3.1.1).

b) Data that are required for an intended operation but are not required to be decoded within six seconds should be transmitted with a maximum time between transmissions of 2 seconds. This rate will allow the generation of a warning upon loss of data within 6 seconds.

c) Operational information data should be transmitted with a maximum time between transmissions of 10 seconds. This will allow the generation of a warning upon loss of data within 30 seconds.

2.7.3 *Application of MLS/RNAV data words B1 through B39*

2.7.3.1 The data contained in auxiliary data words B1-B39 are designed to allow MLS/RNAV operations to be supported utilizing only the data contained within the MLS data words. In order to support computed centre line approaches to both the primary and secondary runways, curved approaches and departures, and missed approaches, these data include information on procedure type (approach or departure), procedure name, runway and way-points.

2.7.3.2 The data transmitted by approach azimuth and back azimuth are segregated. This means, for example, that each will have a separate cyclic redundancy check (CRC) and be decoded independently by the airborne equipment. Data for a given MLS/RNAV procedure are transmitted in the coverage where the procedure begins. Normally this means that approach and missed approach data would be transmitted by approach azimuth and departure data would be transmitted by back azimuth equipment. However, way-points belonging to approaches, missed approaches or departures could be transmitted in either the azimuth or the back azimuth coverage. For example, a departure may be initiated in approach azimuth coverage, therefore that data would be transmitted by approach azimuth. If the procedure begins in a common coverage region the associated data can be transmitted in only one region, except where otherwise dictated by operational requirements.

2.7.3.3 The procedures are defined by a series of way-points. The way-points are specified in a cartesian coordinate system with X, Y and Z coordinates whose origin is at the MLS datum point. The coordinate system is illustrated in Figure G-13.

2.7.3.4 The segments between way-points are either straight or curved. Curved segments are defined as the arc joining two way-points, as illustrated in Figure G-14. The arc of the circle is always tangent to the preceding and following segments, straight or circular. Final approach segments and segments pointing to the initial way-point of an approach procedure or extending from the last flown way-point of a departure or missed approach procedure are always straight. They are extensions to straight segments or tangents to circular segments. These straight segments would not necessarily require a way-point at the edge of the coverage, thus way-points could be saved.

2.7.3.5 For any procedure type the coding starts with the way-point farthest from the threshold and ends with the way-point nearest to the runway. All way-points for approach procedures must be coded before any missed approach way-points or departure way-points. This rule simplifies the decoding by segregating the way-points belonging to the approaches from the others. Several procedures can share one or more way-points. When this is the case it is feasible to transmit this information only once. The shared way-points must be the final ones for approach procedures and the initial ones for missed approach and departure procedures. Approaches, missed approaches and departures can share data provided the data are transmitted in the same coverage sector. When way-points are shared with a procedure previously defined in the database this is indicated by a way-point index following a way-point. The way-point index gives the location in the database of the first shared way-point.

2.7.3.6 The way-point index is the value representing the sequential order in which the way-points are listed in the database. It is used in the coding to indicate where the way-points for a procedure are located. A way-point index of zero in the procedure descriptor indicates that this is a computed centre line application where no way-points are provided.

2.7.3.7 Although way-points are defined by X, Y and Z coordinates, in a variety of cases not all coordinates have to be transmitted. Way-points located on the primary runway centre line have a Y coordinate equal to zero. The corresponding field defining this value can be omitted by setting the “Y coordinate follows” bit to ZERO.

2.7.3.8 Whenever the Z coordinate is not necessary for path construction, data can be saved by not transmitting this value. This is indicated by setting the “Z coordinate follows” bit to ZERO. This may apply to initial way-points preceding the final approach fix where guidance is based on altimetry and not on a computed MLS vertical position. It may also apply to way-points located on a constant gradient between way-points for which the Z value is defined. In this case, the airborne equipment would compute the Z coordinate assuming a constant gradient. Missed approach and departure way-points located in back azimuth coverage are also candidates for deleting the Z coordinate, since vertical guidance is not available. For the back azimuth application, the Z coordinate may be transmitted for use by the airborne equipment to resolve the horizontal position of the aircraft. This allows for a reduction of the lateral errors introduced in the conversion from the slant range and conical back azimuth angle to X-Y coordinates.

2.7.3.9 The 3-bit field following the way-point coordinates contains the next segment/field identifier. This data item indicates whether the next segment of the procedure is straight or curved, whether the current way-point is the last one defined for the procedure, and whether to link the procedure to a missed approach or a shared portion of another procedure identified by a missed approach index or next way-point index. It also indicates whether a data field for threshold crossing height or virtual azimuth to way-point distance is appended to the way-point definition.

2.7.3.9.1 Some typical applications of the identifiers in Appendix A, Table A-17 are listed below. This list is not all inclusive:

a) identifiers 0 and 1 are used when the next way-point in the procedure is not a shared way-point, or is a shared way-point coded for the first time;

b) identifiers 2 and 3 are used to refer to the next way-points in the procedure that are already coded and shared with another procedure. The coding of these way-points is not repeated but the index allows the connection of the procedure to the shared way-points of the other procedure;

c) identifiers 4 and 5 are used in the next-to-last way-point for procedures ending or beginning on the primary runway. The last way-point is the threshold. For this way-point only, the threshold crossing height is specified since the exact location of the threshold with respect to the MLS datum is given in the auxiliary A words. Identifier 4 is used when the MLS/RNAV missed approach guidance is not required, and identifier 5 is used when a “missed approach index” follows;

d) identifiers 6 and 7 are used for the final way-point of any procedure except as noted in c) above. For the primary runway these identifiers are used if there is a need to fully specify the X, Y and Z coordinates of the last way-point. These identifiers are also used for secondary runways and helipads. Identifier 6 is used when no missed approach is following and identifier 7 when a missed approach follows; and

e) identifiers 5 and 7 do not apply to missed approaches and departures.

2.7.3.10 Following the convention for other MLS basic and auxiliary data, all digital data encoded in the database are transmitted with the least significant bit first and the sign bit is transmitted as the most significant bit, with a ONE indicating a negative value. It is noted that the auxiliary data word addresses used to indicate the last approach azimuth database word and the first back azimuth database word are transmitted with the most significant bit first.

2.7.4 *Example application of MLS/RNAV data words*

2.7.4.1 The following paragraphs provide an example of the data assignment process for MLS/RNAV data words contained in auxiliary data words B1-B39. A sample set of approach and departure procedures is provided and the process by which the various way-points and associated procedure characteristics are interpreted and formatted for transmission is described.

2.7.4.2 Table G-3 depicts a set of sample approach, missed approach, and departure procedures for two hypothetical runways. Table G-4 contains way-point data for the sample procedures indicated in Table G-3 and illustrated in Figure G-15.

2.7.4.3 Prior to inserting the procedures data into the structure of B1-B39, the characteristics of the MLS/RNAV data must be understood in order to optimally use the available number of data words. In the data set of Tables G-3 and G-4, the following specific characteristics can be noted: procedures KASEL and NELSO share the same way-points No. 1 (WP 1) and No. 2 (WP 2); procedures KASEL and NELSO link to a missed approach procedure; procedure SEMOR is a secondary runway approach; procedure LAWSO is a departure procedure and will be transmitted in back azimuth coverage; all way-points outside of the precision final approach fix (PFAF) will not require the Z coordinate to be transmitted; the Y coordinate will not have to be transmitted for several way-points that are located on the extended primary runway centre line.

2.7.4.4 Data word B1 specified in Appendix A, Table A-15, defines the structure of the MLS/RNAV data to be transmitted in the approach azimuth coverage sector. This word also contains the approach azimuth CRC code. The number of procedures to be transmitted in the approach azimuth sector is 3. This can be determined from Table G-3. The data word address with the last approach azimuth MLS/RNAV data word is determined after the complete set is inserted into the format. In this case, the address of the last word is B11. The CRC code is calculated as described in Note 3 to Table A-15. Words B42 and B43 are not transmitted so that the relevant bits are set to ZERO. Word A4 is transmitted so that the relevant bit is set to ONE. The coding for data word B1 is shown in Table G-5.

2.7.4.5 Data word B39 specified in Appendix A, Table A-15 defines the structure of the MLS/RNAV data to be transmitted in the back azimuth coverage sector. This word also contains the back azimuth CRC code. The number of procedures to be transmitted in the back azimuth sector is 1. The data word address with the first back azimuth MLS/RNAV data word is determined after the complete set is inserted into the format. In this case the address of the first word is B36. The CRC code is calculated as described in Note 3 to Table A-15. Word B43 is not transmitted so that bit is set to ZERO. The back azimuth map/CRC indicator bit is set to ONE to indicate that this is a map/CRC word. The coding for data word B39 is shown in Table G-5.

2.7.4.6 Procedure descriptor words specified in Appendix A, Table A-15 are defined for all approach and departure procedures. Missed approach procedures are linked to approach procedures in the data format and hence do not require a procedure descriptor. Procedure descriptor words for the sample data set are shown in Table G-6. It is noted that the procedure descriptor data words cannot be fully defined until the completion of the actual assignment of the way-point data due to the need for a "first way-point index" associated with each procedure. This item is the first way-point for the procedure sequence. The index is generated as indicated in 2.7.3.6. It is noted that the "validity indicator" of a procedure name (see Table G-4) is the version number of the procedure and is a value from 1 to 9.

2.7.4.7 The way-point data assignment process is in accordance with Appendix A, Tables A-15, 16 and 17. Table G-7 represents the assignment of the sample data set. The preambles, addresses and parity bits have been left out of the table. Starting with the data word immediately after the approach procedure descriptor words, the first way-point of the first procedure is assigned. For the sample data set, it means that data word B5 is the first word with way-point data. The next step is to insert the data into the appropriate format. The procedures data always commence with the X coordinate of the initial way-point. The structure of the database allows for individual data items to overlap between auxiliary data words. For example, the first 14 bits of the X coordinate of WP 3 of procedure KASEL are transmitted in word B5. The final bit is transmitted in word B6.

2.7.4.7.1 Because of the bit weight of the way-point coordinate least significant bit, the coded way-point coordinate must be rounded. It is desirable to achieve a result as close as possible to the actual way-point coordinate value. Such rounding is normally performed by adding to the actual value half the weight of the LSB then performing integer division on the result. For example, the X coordinate of WP 2 of procedure KASEL is 6 556 m (actual). The coded binary value should be 2 561 since,

$$Integer\left[\frac{\left(|\,6\,556\,| + \frac{2.56}{2}\right)}{2.56}\right] = 2\,561$$

For negative numbers the sign bit should be carried through the calculation.

2.7.4.8 After the X coordinate is the “Y coordinate follows” bit. This bit would be set to zero, and the Y coordinate would not be transmitted as shown in Table G-7 for KASEL WP 2 and WP 1. As shown in KASEL WP 3, the Y coordinate is needed and is transmitted after the “Y coordinate follows” bit.

2.7.4.9 Depending on the coding of the “Y coordinate follows” bit, the “Z coordinate follows” bit is coded after the Y coordinate information. For procedure KASEL, WP 4 does not require the Z coordinate since it is prior to the PFAF. The Z coordinate is also not required for WP 2 because there is a constant glide path between WP 3 and WP 1. As shown in KASEL WP 3, the Z coordinate is needed and is transmitted after the “Z coordinate follows” bit.

2.7.4.10 The next segment/field identifier is assigned in accordance with Appendix A, Table A-17. For the identifier following WP 2 in procedure KASEL, the value 5 indicates that the threshold way-point height is transmitted next, followed by the way-point index of the missed approach procedure. For procedure NELSO, since the last two way-points are shared with procedure KASEL the identifier following WP 3 has the value 3, indicating that the index for the next way-point is transmitted next. In this case the index is 3, pointing to WP 2 of procedure KASEL. For the missed approach procedure the identifier is set to 6, indicating that this is the last way-point in the procedure. For secondary runway procedure SEMOR the identifier is also set to 6. In this case, however, it indicates that the virtual azimuth to way-point distance follows.

2.7.4.11 Table G-8 shows the assignment of the departure procedure way-points. The departure data start with word B36, the procedure descriptor. The way-points data begin with word B37. Departure data are assigned using the same method as for the approach data.

2.7.4.12 After the database is completely assigned, the CRC values may be calculated using B1-B39 and the other required data items. Table G-9 shows the results of this calculation for the sample data set including the auxiliary A words, basic word B6, and auxiliary words B40-B41.

2.8 Adjacent channel interference considerations

2.8.1 The standard has been structured such that there is at least a 5-dB margin to account for variations in the effective radiated power above the minimum power density specification. The interference specification is based upon worst-case antenna beamwidth combinations, data rate, and undesired interference synchronization.

3. Ground equipment

3.1 Scanning beam shape

3.1.1 The azimuth scanning beam envelope on the antenna boresight and the elevation scanning beam envelope at the preferred elevation angle, as detected by a standard receiver, has to conform to the limits specified in Figure G-16 under conditions of high SNR and negligible multipath (e.g. during a trial on an antenna range). The –10 dB symmetry relative to accuracy performance is not necessarily expected in the equipment design.

3.2 Scanning beam side lobes

3.2.1 *Performance specification.* The antenna side-lobe design has to satisfy two conditions: 1) the dynamic side-lobe level does not prevent the airborne receiver from acquiring and tracking the main beam. Satisfactory performance cannot be assured if dynamic side lobes persist at levels above –10 dB; 2) the effective side-lobe level is compatible with the system error budget.

3.2.2 The effective side-lobe level (P_{ESL}) is related to the dynamic side-lobe level (P_{DYN}) by:

$$P_{ESL} = K \times P_{DYN}$$

where K is a reduction factor which depends upon the antenna implementation. The reduction factor may be dependent upon:

a) a directive antenna element pattern which reduces the multipath signal level relative to the coverage volume;

b) the degree of randomness in the dynamic side lobes.

Note.— The dynamic side lobes are of least concern, if the measured dynamic side-lobe levels are less than the specified effective side-lobe levels.

3.2.3 Lateral multipath reflections from the azimuth antenna side lobes and ground multipath reflections from elevation antenna side lobes can perturb the main beam and induce angular errors. To ensure that the error dθ generated by the antenna side lobes is within the propagation error budgets, the required effective side-lobe level ESL can be estimated using:

$$P_{ESL} = \frac{d\theta}{\theta_{BW} P_R P_{MA}}$$

where P_R is the multipath obstacle reflection coefficient, θ_{BW} is the ground antenna beamwidth and P_{MA} is the motion averaging factor.

Note.— A -25 dB P_{ESL} will generally satisfy the propagation error budget in a complex propagation environment.

3.2.4 The motion averaging factor depends on the specific multipath geometry, the aircraft velocity, the function data rate and the output filter bandwidth. For combinations of multipath geometry and aircraft velocity such that the multipath scalloping frequency is greater than 1.6 Hz, the motion factor is:

$$P_{MA} = \sqrt{\frac{2\ (\text{output filter noise bandwidth})}{\text{Function data rate}}}$$

3.2.5 This factor can be further reduced at higher multipath scalloping frequencies where the multipath-induced beam distortions are uncorrelated within the time interval between the TO and FRO scans.

3.3 Approach elevation antenna pattern

3.3.1 If required to limit multipath effects, the horizontal radiation pattern of the approach elevation antenna gradually de-emphasizes the signal away from the antenna boresight. Typically the horizontal pattern of the approach elevation antenna is to be reduced by 3 dB at 20 degrees off the boresight and by 6 dB at 40 degrees. Depending on the actual multipath conditions, the horizontal radiation pattern may require more or less de-emphasis.

a) in the horizontal plane, the antenna is to be sited on extended runway centre line not closer than 300 m to the runway stop end and as far as possible from the nearest light position toward runway stop end. (This places the back of the azimuth equipment against a light position.)

b) the siting of the azimuth station is to be such that the shadowing of the lights of the approach lighting system is minimized, particularly within decision height boundaries. The azimuth station should not shadow any light(s) other than that located in a centre part of a cross bar or a centre line barrette (see Annex 14, Volume I, Attachment A, Section 11.3 for further guidance).

4.2.4.1 If the spacing between adjacent light stations is 30 m (100 ft) or more, the phase centre should be at least 0.3 m (1 ft) above light centre line of the closest light station toward runway stop end. This could be relaxed to 0.15 m (0.5 ft), if necessary, if the site is otherwise free of significant multipath problems. This may require the use of an elevated azimuth station.

4.2.4.2 If the spacing between adjacent light stations is less than 30 m (100 ft), the phase centre should be at least 0.6 m (2 ft) above light centre line of the closest light station toward runway stop end.

4.3 Critical and sensitive areas

4.3.1 The occurrence of interference to MLS signals is dependent on the reflection and shadowing environment around the MLS antennas and the antenna beamwidths. Vehicles and fixed objects within 1.7 beamwidths of the receiver location are considered “in-beam” and will cause main lobe multipath interference to the MLS guidance signals. Typically, the ground equipment beamwidths are chosen such that no azimuth in-beam reflections exist along the final approach course and no elevation in-beam multipath exists along the commissioned glide paths. However, movable objects may enter the in-beam multipath regions and cause interfering reflections to or shadowing of the guidance signals to the extent that the quality becomes unacceptable. The areas within which vehicles can cause degraded performance need to be defined and recognized. For the purpose of developing protective zoning criteria, these areas can be divided into two types, i.e. critical areas and sensitive areas:

a) The MLS critical area is an area of defined dimensions about the azimuth and elevation antennas where vehicles, including aircraft, are excluded during all MLS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the guidance signals.

b) The MLS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the MLS signals during MLS operations. The sensitive area provides protection against interference caused by large objects outside the critical area but still normally within the airfield boundary.

Note 1.— Where disturbance to the guidance signal can occur only at some height above the ground the terms “critical volume” or “sensitive volume” are used.

Note 2.— The objective of defining critical and sensitive areas is to afford adequate protection of the MLS guidance signals. The manner in which the terminology is applied may vary between States. In some States, the term “critical area” is also used to describe the area that is referred to herein as the sensitive area.

4.3.2 Typical examples of critical and sensitive areas that need to be protected are shown in Figure G-23 and Figure G-24. The tabled values associated with Figure G-23 and Figure G-24 apply to approach procedures with elevation angles of three degrees or higher. To assure the signal quality, it is necessary normally to prohibit all entry of vehicles and the taxiing or parking of aircraft within this area during all MLS operations. The critical area determined for each azimuth and elevation antenna should be clearly designated. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical area in order to restrict the entry of vehicles and aircraft.

4.3.3 Computer modelling techniques can be employed to calculate the magnitude and duration of signal disturbances caused by structures or by aircraft of various sizes and orientation at differing locations. Typically, the parameters required to operate such a model are the antenna beamwidths and the size, location and orientation of reflecting and shadowing objects. Taking into account the maximum allowable multipath degradation of the signal due to aircraft on the ground, the corresponding critical and sensitive areas can be determined. Such a method has been used in developing Figures G-23 and G-24, after validation of computer models which included comparisons at selected points of computed results with actual field and flight data on parked aircraft interference to the MLS guidance signals.

4.3.4 Control of critical areas and the designation of sensitive areas on the airport proper generally will be sufficient to protect MLS signals from multipath effects caused by large, fixed ground structures. This is particularly significant when considering the size of new buildings. Structures outside the boundaries of the airport generally will not cause difficulty to the MLS signal quality as long as the structures meet obstacle limitation criteria.

4.3.5 The boundary of the protected zone (i.e. the combined critical and sensitive areas) is defined such that interference caused by aircraft and vehicles outside that boundary will not cause errors in excess of typical allowances for propagation effects. The derivation of error allowances to protect centre line approach profiles, as shown in Tables G-10 and G-11 for a "clean" and "complex" propagation environment, proceed as follows. Allowances for equipment errors are subtracted (on a root sum square basis (RSS)) from the system error limits at the approach reference datum (ARD) and the resulting balance of the error budget is available for propagation anomalies. The ground reflection is accommodated at both clean and complex sites, while in complex environments, a margin is reserved to accommodate additional error sources such as support structure vibration, diffracted signals from, for example, approach lighting system (ALS) lights and supports or more intense lateral reflections. Finally, 70 per cent of the remaining error balance is allocated to define the protected zone boundary. Thus, error balances are available to define protected zone boundaries for the extreme cases of a very clean propagation environment with only ground reflections and for a very complex environment with several significant sources of propagation errors.

4.3.6 The MLS critical areas are smaller than the ILS critical areas. Where MLS antennas are located in close proximity to the ILS antennas, the ILS critical areas in most cases will protect the MLS for similar approach paths.

Note.— A reduction of the MLS critical and sensitive areas may be obtained by measurements or analysis which consider the specific environment. It is recommended that samples be taken at least every 15 m (50 ft).

4.3.7 *Azimuth.* For an azimuth antenna supporting an aligned approach along the zero degree azimuth, the region between the azimuth antenna and runway stop end is to be designated as a critical area. The sensitive area of Figure G-23A provides additional signal protection when low visibility landing operations are in progress. In general, the azimuth sensitive area will fall within the runway boundaries such that adequate control can be exercised over all moving traffic to prevent unacceptable interference to the MLS signals. In developing the sensitive area lengths of Table G-12A, it was assumed that the landed B-727 (or B-747) type aircraft has cleared the runway before the landing aircraft reaches a height of 90 m (300 ft) (or 180 m (600 ft) for B-747)). That assumption resulted from consideration of the following factors:

a) 5.6 km (3 NM) separation behind B-747 size aircraft;

b) 3.7 km (2 NM) separation behind B-727 size aircraft;

c) runway occupancy time for the landing aircraft is 30 seconds; and

d) approaching aircraft speed is approximately 220 km/hr (2 NM/min).

4.3.7.1 For an approach azimuth equipment that supports aircraft guidance on the runway surface, an additional sensitive area has to be protected. Due to the low level of power density received by an aircraft on the ground, with the receiving antenna at the lower limit of the coverage, the relative power density of the azimuth beam diffracted by the fin trailing edge of an aircraft leaving or approaching the runway can be significant and create in-beam multipath effects. Typical surfaces in which no aircraft fin should be present are described in Figure G-23B. There are angular sectors starting from the azimuth antenna, with a semi-width of 1.7 beamwidth centred on the runway centre line. The semi-width is limited at a value given in Table G-12E for an azimuth antenna phase centre 1.4 m (4.6 ft) above a flat runway. In case the power density received on the ground is different from what is expected from propagation above a flat ground, some corrections should be applied. It has been determined, for example, that if the actual power density 2.5 m (8 ft) above the runway is 6 dB higher (due for example to azimuth antenna phase centre two times higher), the sensitive area semi-width can be reduced by 6 m (20 ft) (or increased if the power density is 6 dB lower).

4.3.7.2 For an azimuth antenna supporting an offset approach, the critical and sensitive areas will depend on the azimuth antenna location and the approach track orientation relative to the zero degree azimuth. The critical area extends for at least 300 m (1 000 ft) in front of the azimuth antenna. To avoid shadowing while landing operations are in progress, additional protection is to be provided in the form of a sensitive area. Table G-12B gives sensitive area length for use with an offset azimuth installation. When a procedure is along an azimuth other than the zero degree azimuth, the plan view definition has to take into account beam spreading. Figure G-25 shows typical examples.

Note.— This guidance material also applies to an azimuth antenna providing the back azimuth function.

4.3.7.3 *Critical and sensitive areas for the computed centre line approach.* Figure G-26 provides a general illustration of the areas to be protected from uncontrolled movement of ground traffic. The exact shape of that area will depend on the azimuth antenna location, azimuth to threshold distance, decision height, type of aircraft operating at the facility, and the multipath environment.

4.3.7.3.1 In determining the area to be protected, the following steps are appropriate:

a) determine the direction of line AG (Figure G-26) from the azimuth antenna (point A) to the nearest point to the runway centre line where guidance is required (point G);

b) locate point C on line AG at a distance from the azimuth antenna found by entering Table G-12C or G-12D with azimuth to threshold distance, size of the largest aircraft on ground and height of point G on the minimum glide path;

c) line AB has the same length as line AC and lines AC and AB are angularly separated by an amount for in-beam multipath (1.7 beamwidth) and a value for flight path deviation allowance to account for deviations of the approaching aircraft about the nominal approach track;

d) determine the direction of line AF from the azimuth antenna to point F at a height of 300 m (1 000 ft) on the minimum glide path;

e) determine the direction of line AD which is angularly separated by 1.7 BW from line AF;

f) the length of line AD is taken from Table G-12C or G-12D with information on the height of point F; and

g) the area to be protected is bounded by the polygon ABCD.

4.3.7.3.2 Typically, the areas of polygon ABCD in Figure G-26 within at least the first 300 m (1 000 ft) or 600 m (2 000 ft) of the azimuth antenna are to be designated, respectively, as a critical area where B-727 or B-747 size aircraft are operating. The balance of the region is designated as a sensitive area. Where possible, the azimuth antenna is to be offset to the runway side away from that of active taxiways. At facilities where the azimuth antenna is set back less than 300 m (1 000 ft) or located ahead of the runway stop end, a detailed analysis and consideration of the airport layout may support reductions of the area to be protected.

4.3.7.4 *Critical and sensitive areas for MLS/RNAV procedures.* For MLS/RNAV approach procedures, the critical and sensitive areas will require expansion to protect against in-beam multipath in the sectors used. These expanded areas protect approach procedures which are not possible with ILS. The length of the area to be protected depends on the operational minimum height surface selected from Table G-13. Information for determining the area to be protected is given in Figure G-27. For a wide range of profiles, simulation indicated that, where B-727 size aircraft are operating, adequate protection would be afforded if the first 300 m (1 000 ft) of the protected area is designated as a critical area and the remainder as a sensitive area. For B-747 size aircraft, the corresponding length is 600 m (2 000 ft). For higher approach profiles, the length derived from Table G-13 or an equation therein may be less than these values; in this case the entire expanded area is to be designated as a critical area. Increased flexibility may be obtained by performing an analysis considering the specific approach profile and airport environment.

4.3.8 *Elevation.* The elevation critical area to be protected results from the critical volume shown in Figure G-24. Normally no sensitive area is defined for the elevation antenna. As the lower surface of the critical volume normally is well above ground level, aircraft may hold near the elevation antenna as long as the lower boundary of the critical volume is not penetrated.

4.3.8.1 For normal siting of a 1.0 degree beamwidth elevation antenna and flat ground, the fuselage of most aircraft types will fit under the profile lower surface of the critical volume of Figure G-24.

4.3.8.2 For a 1.5 degree beamwidth elevation antenna, limited penetration of the profile lower surface of the critical volume of Figure G-24 by an aircraft fuselage may be tolerated by defining the lower part of the critical volume between 1.5 degrees and 1.7 beamwidth below the minimum glide path as sensitive volume. At sites performing well within tolerance, aircraft may hold in front of the antenna provided:

a) the separation angle between the glide path and the top of the aircraft fuselage is at least 1.5 degrees;

b) the aircraft tail fin does not penetrate the lower surface of the critical volume; and

c) the fuselage is at right angle to the centre line.

4.3.8.3 For MLS/RNAV approach procedures, the plan view of the elevation critical area will require expansion to ensure the elevation signal quality along the nominal approach track (Figure G-28). These expanded areas protect approach procedures which are not possible with ILS. The characteristics of the profile view (Figure G-24) remain unchanged, noting that the lower boundary is referenced to the nominal approach track. This guidance material covers a wide range of profiles. Increased flexibility may be obtained by performing an analysis considering the specific approach profile and airport environment.

5. Operational considerations on siting of DME ground equipment

5.1 The DME equipment should, whenever possible, provide indicated zero range to the pilot at the touchdown point in order to satisfy current operational requirements.

5.1.1 When DME/P is installed with the MLS, indicated zero range referenced to the MLS datum point may be obtained by airborne equipment utilizing coordinate information from the MLS data. DME zero range should be referenced to the DME/P site.

6. Interrelationship of ground equipment monitor and control actions

6.1 The interrelationship of monitor and control actions is considered necessary to ensure that aircraft do not receive incomplete guidance which could jeopardize safety, but at the same time continue to receive valid guidance which may safely be utilized in the event of certain functions ceasing to radiate.

Note.— The interrelationship of ground equipment monitor and control actions is presented in Table G-14.

7. Airborne equipment

7.1 General

7.1.1 The airborne equipment parameters and tolerances included in this section are intended to enable an interpretation of the Standards contained in Chapter 3, 3.11 and include allowances, where appropriate, for:

a) variation of the ground equipment parameters within the limits defined in Chapter 3, 3.11;

b) aircraft manoeuvres, speeds and attitudes normally encountered within the coverage volume.

Note 1.— The airborne equipment includes the aircraft antenna(s), the airborne receiver, the pilot interface equipment and the necessary interconnections.

Note 2.— Detailed "Minimum Performance Specifications" for MLS avionics have been compiled and coordinated by the European Organization for Civil Aviation Electronics (EUROCAE) and RTCA Inc. ICAO periodically provides to Contracting States current lists of the publications of these organizations in accordance with Recommendations 3/18(a) and 6/7(a) of the Seventh Air Navigation Conference.

7.1.2 *Function decoding*

7.1.2.1 The airborne equipment is to be capable of decoding and processing the approach azimuth, high rate approach azimuth, back azimuth, and approach elevation functions, and data required for the intended operation.

7.1.2.2 In addition, the receiver utilizes techniques to prevent function processing resulting from the presence of function preambles embedded within the data fields of basic and auxiliary data words and scanning beam side lobe radiation. One technique to accomplish this is to decode all function preambles. Following the decode of a preamble, the detection and decoding of all function preambles is then disabled for a period of time corresponding to the length of the function.

7.1.2.3 Range information is decoded independently.

7.1.3 The receiver decodes the full range of angles permitted by the signal format for each function. The guidance angle is determined by measuring the time interval between the received envelopes of the TO and FRO scans. The decoded angle is related to this time interval by the equation given in Chapter 3, 3.11.4.5.

7.1.4 The receiver is capable of normal processing of each radiated function without regard to the position of the function in the transmitted sequences.

7.1.5 If the MLS approach azimuth and back azimuth information is presented on the selector and/or flight instruments, it is to be displayed in magnetic degrees. Receivers in the automatic mode display the relevant information transmitted by the ground station as part of the basic data word 4.

7.1.6 The receiver has the capability for both manual and automatic selection of approach track, elevation angle and back azimuth radial when provided. When in automatic mode, the selection is made as follows.

7.1.6.1 *Approach azimuth* — select the angular reciprocal of the approach azimuth magnetic orientation in basic data word 4.

7.1.6.2 *Elevation angle* — select the minimum glide path in basic data word 2.

7.1.6.3 *Back azimuth* — select the angle of the back azimuth magnetic orientation in basic data word 4.

Note.— The receiver indicates when deviation is referenced to the back azimuth signal.

7.1.7 The MLS airborne receiver system must have an integrity compatible with the overall integrity of MLS which is at least $1 - 1 \times 10^{-7}$ in any one landing.

7.1.8 For airborne equipment used in MLS/RNAV operations the capability is to be provided to unambiguously display the procedure selected.

7.2 Radio frequency response

7.2.1 *Acceptance bandwidth*

7.2.1.1 The receiver should meet acquisition and performance requirements when the received signal frequency is offset by up to plus or minus 12 kHz from the normal channel centre frequency. This figure considers possible ground transmitter offsets of plus or minus 10 kHz and Doppler shifts of plus or minus 2 kHz. The receiver should decode all functions independently of the different frequency offsets of one function relative to another.

7.2.2 *Selectivity*

7.2.2.1 When the receiver is tuned to an inoperative channel and an unwanted MLS signal of a level 33 dB above that specified in Chapter 3, 3.11.4.10.1 for the approach azimuth DPSK is transmitted on any one of the remaining channels, the receiver should not acquire the signal.

7.2.3 *In-channel spurious response*

7.2.3.1 The receiver performance specified in Chapter 3, 3.11.6, should be met when, in addition, interference on the same channel is received at a level not exceeding that specified in Chapter 3, 3.11.4.1.4.

7.2.4 *Interference from out-of-band transmissions*

7.2.4.1 The receiver performance in Chapter 3, 3.11.6 is to be met when, in addition, interference from undesired signals is received at a level not exceeding –124.5 dBW/m^2 at the MLS receiver antenna.

7.3 Signal processing

7.3.1 *Acquisition*

7.3.1.1 The receiver should, in the presence of an input guidance signal which conforms to the requirements of Chapter 3, 3.11.4, acquire and validate the guidance signal before transitioning to the track mode within two seconds along the critical portion of the approach and within six seconds at the limits of coverage.

7.3.1.2 Approach or high-rate approach azimuth guidance acquisitions are not allowed below 60 m (200 ft).

Note.— Acquisition below 60 m (200 ft) may lead to acquisition of false guidance, as the multipath signal level may be above direct signal level. Aircraft power loss or pilot tuning are potential causes of acquisition below 60 m (200 ft). Technical or operational measures should be taken to prevent such acquisition.

7.3.2 *Tracking*

7.3.2.1 While tracking, the receiver should provide protection against short duration (less than one second) large amplitude spurious signals. When track is established, the receiver should output valid guidance information before removing the warning. During track mode, the validation process should continue to operate.

7.3.2.2 After loss of the tracked signal for more than one second, the receiver should provide a warning signal. Within the one-second interval, the guidance information should remain at the last output value.

Note 1.— A validated guidance signal is one that satisfies the following criteria:

a) the correct function identification is decoded;

b) the preamble timing signal is decoded;

c) the "TO" and "FRO" scanning beams or left/right clearance signals are present and symmetrically located with respect to the midpoint time; and

d) the detected beamwidth is from 25 to 250 microseconds.

Note 2.— Guidance signal validation also requires that the receiver repeatedly confirm that the signal being acquired or tracked is the largest signal for at least one second.

7.3.2.3 The aircraft should be on the runway centre line or on the selected azimuth angle at 60 m (200 ft) and the receiver has to be in tracking mode. Below that height, the receiver should keep tracking the approach azimuth or high rate approach azimuth signal as far as this signal is coding an angle within a narrow sector centred on the runway centre line or on the selected azimuth angle even if other signals are up to 10 dB higher than the tracked signal.

7.3.3 *Data functions*

7.3.3.1 *Data acquisition.* Performance in the airborne acquisition of data provided on either the basic or auxiliary data function is broken into two items: the time allowed to acquire the data and the probability of an undetected error in the acquired data.

7.3.3.1.1 At the minimum signal power density, the time to acquire basic data word 2 which is transmitted at a rate of 6.25 Hz does not exceed two seconds on a 95 per cent probability basis. The time to acquire data that are transmitted at a rate of 1 Hz does not exceed 6 seconds on a 95 per cent probability basis.

7.3.3.1.2 In the acquisition process, the receiver decodes the appropriate data words and applies certain tests to ensure that the probability of undetected errors does not exceed 1×10^{-6} at the minimum signal power density for those data requiring this level of integrity. The recommended performance specifications for undetected errors may require additional airborne processing of the data beyond simple decoding. For example, these may be achieved by processing multiple samples of the same data words.

7.3.3.1.3 If the receiver does not acquire data required for the intended operation, a suitable warning is to be provided.

7.3.3.1.4 At the minimum signal power density the time to acquire all data words required to support MLS/ RNAV operations (auxiliary data words B1-B41, A1/B42, A2, A3, A4/B43 and basic data word 6) must not exceed 20 seconds on a 95 per cent probability basis. The MLS/RNAV equipment has to ensure that the probability of undetected errors for this block of data does not exceed 0.5×10^{-9}. This performance assumes a 2 dB improvement in signal to noise. This may be achieved through reduced cable loss, margin or improved receiver sensitivity (see the airborne power budget given in Table G-2). Additionally, with signal levels above this, the acquisition time is intended to be less than 20 seconds.

7.3.3.2 *Data validation.* After acquisition of data, the receiver repeatedly confirms that the data being received are the same as the acquired data. The receiver decodes several consecutive and identical data different from that previously acquired before taking action to accept the new decoded data.

7.3.3.2.1 For data required to support MLS/RNAV operations, the airborne equipment applies the cyclic redundancy check (CRC) to the data to ensure sufficient integrity has been achieved. Data that continue to be received continue to be validated. The MLS/RNAV equipment does not accept a new block of data to be used until it is validated with the CRC.

7.3.3.3 *Data loss.* Within 6 seconds after the loss of basic data or auxiliary data that is transmitted with a maximum interval of 2 seconds or less, the receiver provides a suitable warning and removes the existing data. Within 30 seconds after the loss of auxiliary data other than that referred to above, the receiver provides a suitable warning.

7.3.3.3.1 For data required to support MLS/RNAV operations, the airborne equipment does not remove existing data following validation except under the conditions described in 7.3.3.2.1. An MLS/RNAV data block that has been validated by the CRC is not removed until a new data block has been received with a different ground equipment identification in basic data word 6, a new MLS channel is selected, or power is removed. Additionally the data block is not removed when transitioning to back azimuth coverage.

7.3.4 *Multipath performance*

7.3.4.1 Where the radiated signal power density is high enough to cause the airborne equipment thermal noise contribution to be insignificant, the following specifications should apply for scalloping frequencies between 0.05 Hz and 999 Hz.

7.3.4.1.1 *In-beam multipath.* Multipath signals coded less than two beamwidths from the direct signal and with amplitudes of 3 dB or more below the direct signal should not degrade the angle guidance accuracy output by more than plus or minus 0.5 beamwidth (peak error). The receiver should not lose track when such conditions occur.

7.3.4.1.2 *Out-of-beam multipath.* Multipath signals coded 2 beamwidths or more from the direct signal and with amplitudes of 3 dB or more below the direct signal should not degrade the angle guidance accuracy by more than plus or minus 0.02 beamwidth. For azimuth signals, and within a narrow sector around the centre line or around the selected azimuth angle, multipath signals with amplitudes of up to 10 dB above the direct signal and not distorting the direct beam shape as specified in Chapter 3, 3.11.5.2.1.3, should not degrade the angle guidance accuracy by more than plus or minus 0.02 beamwidth. The receiver should not lose track when such conditions occur.

7.3.5 *Clearance*

7.3.5.1 The airborne equipment should provide clearance guidance information whenever the antenna is in the presence of a valid clearance guidance signal.

7.3.5.2 When the decoded angle indication is outside the proportional guidance sector defined in Appendix A, Table A-7, the MLS guidance signal should be interpreted as clearance guidance.

7.3.5.3 When clearance pulses are transmitted, the receiver shall be able to process the range of pulse envelope shapes that may appear in the transition between clearance and scanning beam signals. A particular pulse envelope is dependent on the receiver position, scanning antenna beamwidth, and the relative phase and amplitude ratios of the clearance and scanning beam signals as shown in Figure G-8. The receiver is also required to process rapid changes of indicated angle of the order of 1.5 degrees (peak amplitude) when outside the proportional guidance limits.

7.3.5.4 In receivers with the capability to select or display azimuth angle guidance information greater than plus or minus 10 degrees, the proportional coverage limits in basic data must be decoded and used to preclude use of erroneous guidance.

7.4 Control and output

7.4.1 *Approach azimuth and approach elevation deviation scale factor*

7.4.1.1 *Approach azimuth.* When the approach azimuth deviation information is intended to have the same sensitivity characteristics as ILS, it is a function of the "approach azimuth antenna to threshold distance", as supplied by the basic data, in accordance with the following table:

Approach azimuth antenna to threshold distance (ATT)	Nominal course width
0 – 400 m	± 3.6 degrees
500 – 1 900 m	± 3.0 degrees
2 000 – 4 100 m	$\pm \arctan\left(\frac{105}{\text{ATT}}\right)$ degrees
4 200 – 6 300 m	± 1.5 degrees

7.4.1.2 *Approach elevation.* The deviation information is a continuous function of the manually or automatically selected elevation angle (Θ) in accordance with the formula Θ/4 = half a nominal glide path width, so that glide path widths are nominally in accordance with the following examples:

Selected elevation angle (degrees)	Nominal glide path width (degrees)
3	± 0.75
7.5	± 1.875

Note.— These sensitivity characteristics are applicable to elevation angles up to 7.5 degrees.

7.4.2 *Angle data output filter characteristics*

7.4.2.1 *Phase lags.* To assure proper autopilot interface, the receiver output filter, for sinusoidal input frequencies, does not include phase lags which exceed:

a) 4 degrees from 0.0 to 0.5 rad/s for the azimuth function; and

b) 6.5 degrees from 0.0 to 1.0 rad/s and 10 degrees at 1.5 rad/s for the elevation function.

7.4.3 *Minimum glide path.* When there is capability of selecting the approach elevation angle, a suitable warning is to be issued if the selected angle is lower than the minimum glide path as provided in basic data word 2.

7.4.4 *Status bits.* A suitable warning is to be provided when the function status bits in acquired basic data indicate that the respective function is not being radiated or is being radiated in test mode.

7.5 Use of back azimuth guidance for missed approaches and departures

7.5.1 *Usable back azimuth angles*

7.5.1.1 Flight test results indicated that back azimuth angles of up to ±30 degrees from the runway centre line can be used for navigation guidance for missed approaches and departures. With appropriate interception techniques, larger angle offsets might be acceptable up to the flyable limits of back azimuth coverage. Departure guidance can utilize the back azimuth signal for centre line guidance throughout the take-off roll and initial departure. It is intended that a turn to intercept the back azimuth is initiated at an operationally acceptable altitude, and the prescribed procedure is protected according to appropriate obstacle clearance criteria.

7.5.2 *Back azimuth deviation scale*

7.5.2.1 The scaling of back azimuth deviations must be sufficient to support back azimuth departures and missed approaches not aligned with the approach azimuth, as well as missed approach and departure tracks aligned with the approach azimuth. Deviation scaling effects are most pronounced when manoeuvring to intercept a back azimuth. Very sensitive scaling will cause lateral overshoots and limit flyability of the signal, whereas very insensitive scaling will result in the large consumption of airspace. A nominal course width sensitivity of ±6 degrees provides for an acceptable interception of back azimuth during missed approach and departure.

7.5.3 *Approach azimuth to back azimuth switching*

7.5.3.1 Following initiation of a missed approach using back azimuth guidance, the guidance must switch from approach azimuth to back azimuth. The switching, either automatically or manually, from approach azimuth to back azimuth guidance is intended to provide continuous flyable guidance throughout the missed approach sequence. Switching is not expected to occur until the aircraft receives a validated back azimuth signal, but it is intended to occur before the approach azimuth guidance becomes too sensitive to fly. Switching based on loss of approach azimuth may not occur until the aircraft is very close to the approach azimuth antenna resulting in unflyable guidance. Switching based only on loss of elevation guidance may occur prior to the aircraft receiving a valid back azimuth signal. However, switching might be based on loss of elevation guidance once the back azimuth signal has been validated. Automatic switching at or near the mid-point between azimuth antennas will provide a method which results in continuous guidance during the transition. The mid-point switching methodology may require the use of DME information by the MLS receiver. Precautions are to be taken so that approach to back azimuth switching does not automatically occur unless a missed approach has been initiated.

8. Operations at the limits of and outside the promulgated MLS coverage sectors

8.1 The limits of the azimuth proportional guidance sectors are transmitted in basic data words 1 and 5. These limits do not indicate the maximum flyable MLS approach and back azimuth angles which will normally be at some angle inside these limits. For example, for an approach azimuth providing a proportional guidance sector of ±40 degrees, flyable MLS approach azimuth angles with a full course width of ±3 degrees will exist to approximately ±37 degrees. For a back azimuth, flyable back azimuth angles with full course width will exist to within 6 degrees of the proportional guidance sector limits.

8.2 The basic MLS antenna designs should preclude the generation of unwanted signals outside coverage. Under some unusual siting conditions, MLS signals might be reflected into regions outside the promulgated coverage with sufficient strength to cause erroneous guidance information to be presented by the receiver. As in current procedure the implementing authority would specify operational procedures based on the use of other navaids to bring the aircraft into landing system coverage without transiting the area of concern or may publish advisories which alert pilots to the condition. In addition, the MLS signal format permits the use of two techniques to further reduce the probability of encountering erratic flag activity.

8.2.1 If the undesired MLS signals are reflections and if operational conditions permit, the coverage sector can be adjusted (increased or decreased) such that, at the receiver, either the direct signal is greater than any reflection or the reflector is not illuminated. This technique is referred to as coverage control.

8.2.2 Out-of-coverage indication signals can be transmitted into the out-of-coverage sectors for use in the receiver to ensure a flag whenever an undesired angle guidance signal is present. This is accomplished by transmitting an out-of-coverage indication signal into the region which is greater in magnitude than the undesired guidance signal.

8.3 If it is operationally required to confirm the selected MLS channel outside the promulgated coverage sectors of the MLS, it is intended that this confirmation be derived from the identification of the associated DME. MLS status information is not available outside the promulgated MLS coverage sectors.

9. Separation criteria in terms of signal ratios and propagation losses

9.1 Geographical separation

9.1.1 The separation criteria are provided in 9.2 and 9.3 as desired signal-to-noise ratios and when combined with appropriate propagation losses allow evaluation of MLS C-Band frequency assignments as regards on-channel and adjacent

Table G-12D. Typical azimuth sensitive area lengths
(computed centre line approach, see 4.3.7.2, complex sites)
(distances are in metres (feet); values in both units have been rounded)

Azimuth to threshold distance	2.0° beamwidth					1.0° beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
B-727, complex site								
Height: 300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)
300 (1 000)	300 (1 000)	300 (1 000)	330 (1 100)	460 (1 500)	550 (1 800)	490 (1 600)	520 (1 700)	550 (1 800)
300 (1 000)	300 (1 000)	330 (1 100)	330 (1 100)	490 (1 600)	550 (1 800)	580 (1 900)	610 (2 000)	730 (2 400)
330 (1 100)	330 (1 100)	330 (1 100)	490 (1 600)	550 (1 800)	670 (2 200)	700 (2 300)	790 (2 600)	880 (2 900)
330 (1 100)	330 (1 100)	550 (1 800)	640 (2 100)	730 (2 400)	1 010 (3 300)	940 (3 100)	1 040 (3 400)	1 160 (3 800)
640 (2 100)	640 (2 100)	790 (2 600)	940 (3 100)	1 070 (3 500)	1 250 (4 100)	1 250 (4 100)	1 280 (4 200)	1 430 (4 700)
B-747, clean site								
300 (1 000)	430 (1 400)	460 (1 500)	490 (1 600)	520 (1 700)	670 (2 200)	550 (1 800)	580 (1 900)	610 (2 000)
75 (250)	670 (2 200)	760 (2 500)	820 (2 700)	880 (2 900)	1 010 (3 300)	980 (3 200)	1 070 (3 500)	1 130 (3 700)
60 (200)	730 (2 400)	820 (2 700)	920 (3 000)	1 010 (3 300)	1 130 (3 700)	1 040 (3 400)	1 070 (3 500)	1 220 (4 000)
45 (150)	820 (2 700)	880 (2 900)	980 (3 200)	1 100 (3 600)	1 220 (4 000)	1 100 (3 600)	1 190 (3 900)	1 430 (4 700)
30 (100)	920 (3 000)	1 010 (3 300)	1 130 (3 700)	1 280 (4 200)	1 430 (4 700)	1 580 (5 200)	1 770 (5 800)	1 950 (6 400)
15 (50)	1 100 (3 600)	1 370 (4 500)	1 620 (5 300)	1 830 (6 000)	2 130 (7 000)	2 230 (7 300)	2 350 (7 700)	2 380 (7 800)

Table G-12E. Typical azimuth sensitive area semi-width to protect roll-out guidance (see 4.3.7)
(distances are in metres (feet))

Azimuth to threshold distance	2.0°beamwidth					1.0°beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
Clean/complex site	38 (123)	48 (157)	59 (193)	70 (230)	83 (271)	54 (177)	62 (202)	69 (227)

Table G-13. Minimum height surface angle and related protected coverage volume lengths for MLS/RNAV approach procedures

Protected coverage volume length L[m(ft)] PCH = 2.0 m	Minimum height surface angle (degrees), θ	
	B-727	B-747
300 (1 000)	1.81	3.49
450 (1 500)	1.23	2.36
600 (2 000)	0.95	1.79
750 (2 500)	0.77	1.44
900 (3 000)	N/A	1.21

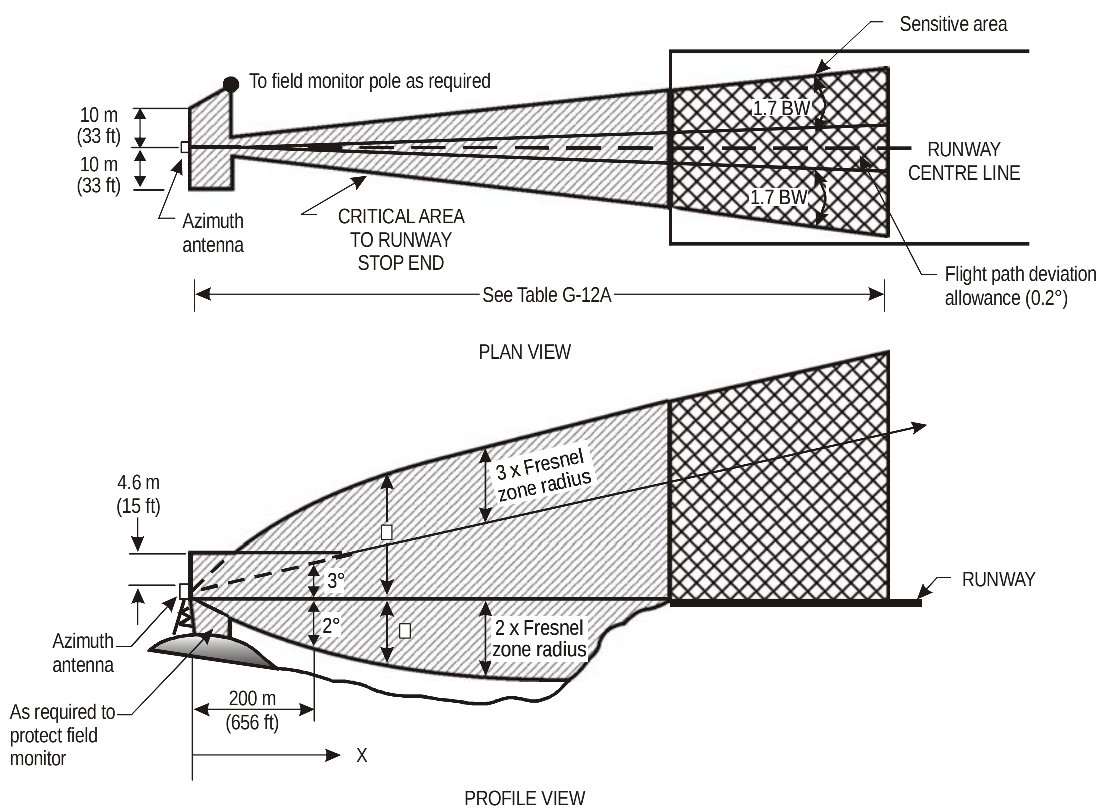
The following equation can be used to determine the minimum height surface angle (Θ) in respect to an azimuth antenna phase centre for arbitrary protected coverage volume length "L".

$$\theta = \tan^{-1}\left[\frac{\mathrm{TFH} + \frac{\sqrt{\lambda(\mathrm{L})}}{4} - \mathrm{PCH}}{\mathrm{L}}\right]$$

where:

TFH = tail fin height;
PCH = phase centre height of MLS antenna;
λ = MLS wave length.

Note.— TFH equals 10.4 m for B-727 and 19.3 m for B-747, and λ is 0.06 m. PCH and L must be in metres if TFH and λ are in metres.



VALUE FOR α and β

* X m (ft)	** α m (ft)	** β m (ft)
30 (100)	1.1 (3.5)	5.7 (18.6)
75 (250)	2.7 (8.7)	10.5 (34.3)
150 (500)	5.3 (17.5)	17.1 (56.2)
225 (750)	7.5 (24.5)	23.2 (76.0)
300 (1 000)	8.6 (28.3)	28.9 (94.8)

Where:

$\alpha = 0.035\,X$ $X < 200$ m

$\alpha = 2\sqrt{0.06\,X}$ $X > 200$ m

$\beta = X \tan 3° + 3\sqrt{0.06\,X}$

* MEASURED HORIZONTALLY FROM AZIMUTH ANTENNA

** MEASURED VERTICALLY FROM BOTTOM OF AZIMUTH ANTENNA APERTURE

BW = BEAMWIDTH

Figure G-23A. Typical azimuth critical and sensitive areas

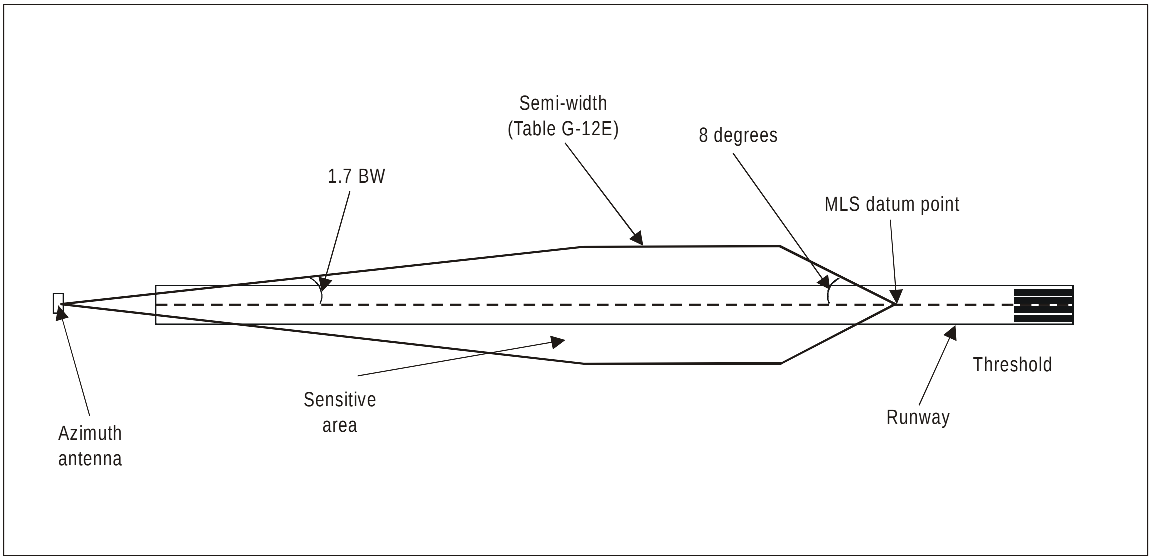


Figure G-23B. Typical azimuth sensitive area to protect roll-out guidance

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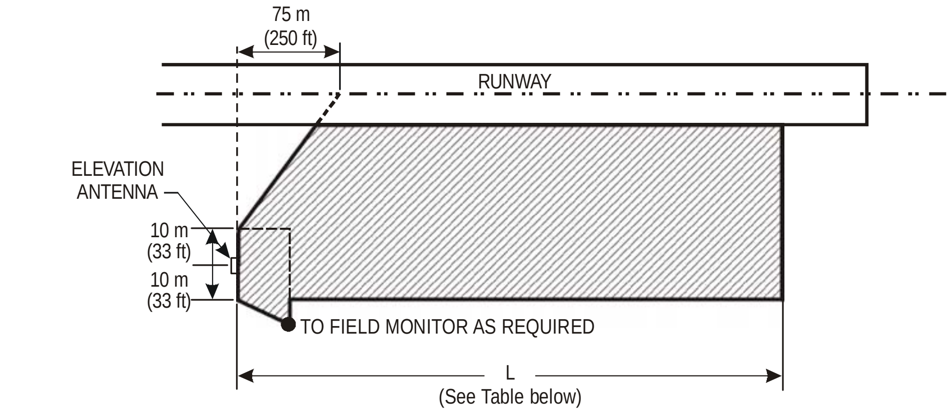
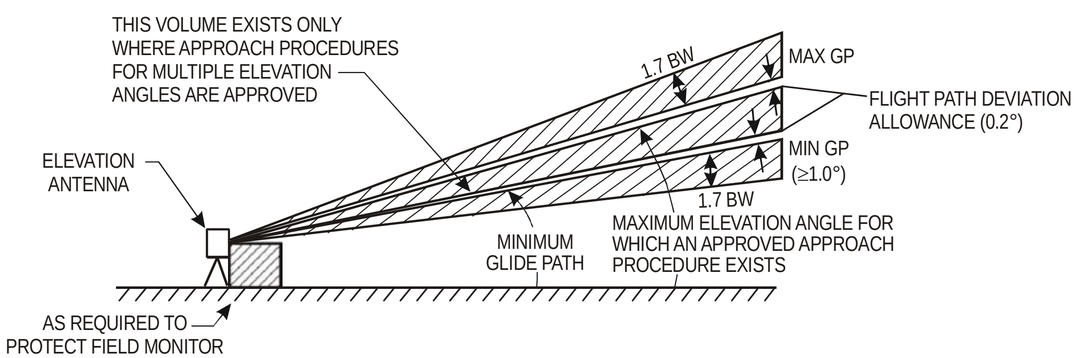


BEAMWIDTH	CLEAN SITE		COMPLEX SITE	
	B-747	B-727	B-747	B-727
1.0°	320 m (1 050 ft)	170 m (560 ft)	385 m (1 260 ft)	180 m (600 ft)
1.5°	400 m (1 310 ft)	250 m (820 ft)	565 m (1 860 ft)	300 m (990 ft)

PLAN VIEW



PROFILE VIEW

Figure G-24. Typical elevation critical and sensitive areas/volume