INTERNATIONAL STANDARDS,
RECOMMENDED PRACTICES AND
PROCEDURES FOR AIR NAVIGATION SERVICES

AERONAUTICAL TELECOMMUNICATIONS

ANNEX 10

TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I

**(PART I — EQUIPMENT AND SYSTEMS;
PART II — RADIO FREQUENCIES)**

FOURTH EDITION OF VOLUME I — APRIL 1985

This edition incorporates all amendments adopted by the Council prior to 6 December 1984 and supersedes, on 21 November 1985, all previous editions of Annex 10.

For information regarding the applicability of the Standards and Recommended Practices and the Procedures for Air Navigation Services, *see* Foreword.

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INTERNATIONAL CIVIL AVIATION ORGANIZATION

AMENDMENTS

The issue of amendments is announced regularly in the *ICAO Bulletin* and in the monthly *Supplement to the Catalogue of ICAO Publications*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

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No.	Date Applicable	Date entered	Entered by
1-65	Incorporated in this edition		

CORRIGENDA			
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FOREWORD

Historical Background

Standards and Recommended Practices for Aeronautical Telecommunications were first adopted by the Council on 30 May 1949 pursuant to the provisions of Article 37 of the Convention on International Civil Aviation (Chicago 1944) and designated as Annex 10 to the Convention. They became effective on 1 March 1950. The Standards and Recommended Practices were based on recommendations of the Communications Division at its Third Session in January 1949.

Table A shows the origin of Annex 10, and the origin of subsequent amendments, together with a summary of the principal subjects involved and the dates on which the Annex and the amendments were adopted by Council, when they became effective and when they became applicable.

Action by Contracting States

Notification of differences. The attention of Contracting States is drawn to the obligation imposed by Article 38 of the Convention by which Contracting States are required to notify the Organization of any differences between their national regulations and practices and the International Standards contained in this Annex and any amendments thereto. Contracting States are invited to extend such notification to any differences from the Recommended Practices contained in this Annex and any amendments thereto, when the notification of such differences is important for the safety of air navigation. Further, Contracting States are invited to keep the Organization currently informed of any differences which may subsequently occur, or of the withdrawal of any differences previously notified. A specific request for notification of differences will be sent to Contracting States immediately after the adoption of each amendment to this Annex.

The attention of States is also drawn to the provisions of Annex 15 related to the publication of differences between their national regulations and practices and the related ICAO Standards and Recommended Practices through the Aeronautical Information Service, in addition to the obligation of States under Article 38 of the Convention.

Promulgation of information. The establishment and withdrawal of and changes to facilities, services and procedures affecting aircraft operations provided in accordance with the Standards, Recommended Practices and Procedures specified in Annex 10, Volumes I and II, should be notified and take effect in accordance with the provisions of Annex 15.

Use of the text of the Annex in national regulations. The Council, on 13 April 1948, adopted a resolution inviting the attention of Contracting States to the desirability of using in their own national regulations, as far as practicable, the precise language of those ICAO Standards that are of a regulatory character and also of indicating departures from the Standards, including any additional national regulations that were important for the safety or regularity of air navigation. Wherever possible, the provisions of this Annex have been deliberately written in such a way as would facilitate incorporation, without major textual changes, into national legislation.

Status of Annex Components

An Annex is made up of the following component parts, not all of which, however, are necessarily found in every Annex; they have the status indicated:

1.—*Material comprising the Annex proper:*

a) *Standards* and *Recommended Practices* adopted by the Council under the provisions of the Convention. They are defined as follows:

Standard: Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

Recommended Practice: Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.

b) *Appendices* comprising material grouped separately for convenience but forming part of the Standards and Recommended Practices adopted by the Council.

c) *Definitions* of terms used in the Standards and Recommended Practices which are not self-explanatory in that they do not have accepted dictionary meanings. A definition does not have independent status but is an essential part of each Standard and Recommended Practice in which the term is used, since a change in the meaning of the term would affect the specification.

d) *Tables* and *Figures* which add to or illustrate a Standard or Recommended Practice and which are

referred to therein, form part of the associated Standard or Recommended Practice and have the same status.

2.—*Material approved by the Council for publication in association with the Standards and Recommended Practices:*

a) *Forewords* comprising historical and explanatory material based on the action of the Council and including an explanation of the obligations of States with regard to the application of the Standards and Recommended Practices ensuing from the Convention and the Resolution of Adoption;

b) *Introductions* comprising explanatory material introduced at the beginning of parts, chapters or sections of the Annex to assist in the understanding of the application of the text;

c) *Notes* included in the text, where appropriate, to give factual information or references bearing on the Standards or Recommended Practices in question, but not constituting part of the Standards or Recommended Practices;

d) *Attachments* comprising material supplementary to the Standards and Recommended Practices, or included as a guide to their application.

Selection of Language

This Annex has been adopted in four languages — English, French, Russian and Spanish. Each Contracting State is requested to select one of those texts for the purpose of national implementation and for other effects provided for in the Convention, either through direct use or through translation into its own national language, and to notify the Organization accordingly.

Editorial Practices

The following practice has been adhered to in order to indicate at a glance the status of each statement: *Standards* have been printed in light face roman; *Recommended Practices* have been printed in light face italics, the status being indicated by the prefix **Recommendation;** *Notes* have been printed in light face italics, the status being indicated by the prefix *Note.*

The following editorial practice has been followed in the writing of specifications: for Standards the operative verb "shall" is used, and for Recommended Practices the operative verb "should" is used.

The units of measurement used in this document are in accordance with the International System of Units (SI) as specified in Annex 5 to the Convention on International Civil Aviation. Where Annex 5 permits the use of non-SI alternative units these are shown in parentheses following the basic units. Where two sets of units are quoted it must not be assumed that the pairs of values are equal and interchangeable. It may, however, be inferred that an equivalent level of safety is achieved when either set of units is used exclusively.

Any reference to a portion of this document, which is identified by a number and/or title, includes all subdivisions of that portion.

Table A. Amendments to Annex 10, Volume I

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
1st Edition	Third Session of the Communications Division	Introduction of Standards and Recommended Practices for radio navigation aids and communication facilities, together with methods of operation, procedures and codes for world-wide application.	30 May 1949 1 March 1950 1 April 1950
1	Third Session of the Communications Division	Amendment to provisions for radio teletypewriter terminal equipment in the band 3-30 MHz.	28 March 1951 1 October 1951 1 January 1952
2*	Third Session of the Communications Division	Addition of guidance material concerning radio teletypewriter system engineering.	28 March 1951 1 October 1951 1 January 1952
3	Third Session of the Communications Division	Standards and Recommended Practices relating to radio frequencies.	28 March 1951 1 October 1951 1 January 1952
4	Third Session of the Communications Division	Standards and Recommended Practices relating to communications procedures.	28 March 1951 1 October 1951 1 April 1952

* Did not affect any Standards or Recommended Practices.

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
5	Third Session of the Communications Division	Standards and Recommended Practices relating to codes and abbreviations.	28 March 1951 1 October 1951 1 April 1952
6	Third Session of the Communications Division	Q Code.	1 April 1952 4 July 1952 1 September 1952
7	Air Navigation Commission	Introduction of definitions for height, altitude and elevation in Annex 10.	17 June 1952 1 December 1952 1 April 1953
8	Fourth Session of the Communications Division	Amendments concerning definitions, VHF radiotelegraph for aural reception, DME, SRE, NDB, 75 MHz en-route marker beacons, ILS.	17 June 1952 1 December 1952 1 April 1953
9	Fourth Session of the Communications Division	Provisions concerning the utilization of offset frequency simplex.	17 June 1952 1 December 1952 1 April 1953
10	Fourth Session of the Communications Division	Definitions and procedures relating to the AFS, AMS and Broadcasts.	17 June 1952 1 December 1952 1 April 1953
11	Secretariat proposal	Editorial amendments consequential to Amendment 7, and editorial improvements to Part IV.	17 June 1952 1 December 1952 1 April 1953
12	Fourth Session of the Communications Division	Annulment of 5.1.6.7 of Amendment 10 adopted by Council on 17 June 1952.	28 November 1952 1 March 1953 1 April 1953
13	Proposal by Ireland on Recommendations of the Fourth Session of the Communications Division	Procedure governing the relay of traffic between an aeronautical station and an aircraft no longer in radio contact.	5 May 1953 15 August 1953 1 October 1953
14	First Air Navigation Conference	Specifications for the siting of ILS marker beacons, VHF equisignal localizers and associated monitors.	11 December 1953 1 May 1954 1 June 1954
15	Fifth Session of the Communications Division	Amendment of paired frequencies for ILS localizers and glide paths.	2 November 1954 1 March 1955 1 April 1955
16	Fifth Session of the Communications Division	Provision of additional assignable frequencies in the VHF bands by extending the allotment table and by making provision for decreasing, under certain conditions, the minimum separation between channels.	2 November 1954 1 March 1955 1 April 1955
17	Fifth Session of the Communications Division	Addition of Standards and Recommended Practices on interim long distance radio navigation aids and on communications systems; also updating of the ILS specifications.	10 December 1954 1 April 1955 1 October 1955
18	Fifth Session of the Communications Division	Establishment of basic rules for the selection of frequencies for radio navigation aids operating in frequency bands above 30 MHz, including frequencies for secondary radar.	10 December 1954 1 April 1955 1 October 1955

Amendment	*Source(s)*	*Subject(s)*	*Adopted* *Effective* *Applicable*
19	Fifth Session of the Communications Division	Procedure to facilitate downgrading or cancellation of messages not delivered within time specified by originator and requirement for specification of aircraft heading in distress message.	10 December 1954 1 April 1955 1 October 1955
20	Fifth Session of the Communications Division	Amendment of codes and abbreviations.	10 December 1954 1 April 1955 1 October 1955
21	Third North Atlantic Regional Air Navigation Meeting	Alignment of radiotelegraphy messages originating in aircraft with radiotelephony messages.	27 May 1955 1 September 1955 1 October 1955
22	Fifth Session of the Communications Division	Pairing of localizer and glide path frequencies for the ILS.	18 November 1955 1 April 1956 1 December 1956
23	Air Navigation Commission	Amendment concerning words to be used in spelling in radiotelephony.	18 November 1955 1 March 1956 1 March 1956
24	Fourth Session of the Meteorology Division	Amendment of Q code signal QBB.	18 November 1955 1 April 1956 1 December 1956
25*	Annex 3	Amendment of the Q code signal QUK (consequential to amendment of Annex 3).	8 November 1955 — 1 January 1956
26	Annex 15	New definition of NOTAM and references to NOTAM (consequential to amendment of Annex 15).	22 February 1956 1 July 1956 1 December 1956
27	Second Air Navigation Conference	Siting of the inner and middle markers of the ILS and guidance material on the location of the ILS reference point.	11 May 1956 15 September 1956 1 December 1956
28	Procedures of the World Meteorological Organization (WMO) and Annex 3	Amendment of the Q code signals for the reporting of clouds and the introduction of the AIREP reporting procedure.	15 May 1956 15 September 1956 1 December 1956
29	Proposal by Australia	Tape-relay Standards.	4 June 1957 1 October 1957 1 December 1957
30*	Annex 3	Amendment of the Q code signals QUK and QUL (consequential to amendment of Annex 3).	25 November 1957 — 1 December 1957
31	Proposal by France	Amendment of the Q code signals QNH and QNY.	21 March 1958 1 August 1958 1 December 1958
32	Sixth Session of the Communications Division	Recommendations of the Meeting.	9 June 1958 1 October 1958 1 December 1958

* Did not affect any Standards or Recommended Practices.

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
33	ICAO Panel of Teletypewriter Specialists (TTP)	Communication operational procedures to ensure compatibility between AFTN communication centres employing manual "torn-tape", semi-automatic and fully automatic operation.	15 December 1958 1 May 1959 1 October 1959
34	Rules of the Air, Air Traffic Services and Search and Rescue Division	Increased number of radio frequencies that may be selected for use in radio survival equipment.	8 December 1959 1 May 1960 1 August 1960
35	Special Communications/Operations/ Rules of the Air, Air Traffic Services and Search and Rescue Division	Implementation requirements for VOR, introduction of new DME specification and extension of protection dates for VOR and DME to 1 January 1975.	8 April 1960 1 August 1960 1 January 1961
36	Air Navigation Commission	Substituted "Radiotelephony Speech for International Aviation" for "International Language for Aviation".	8 April 1960 1 August 1960 1 January 1961
37	Fifth Session of the Meteorology Division Aeronautical Information Services and Aeronautical Charts Division	Procedures respecting the forwarding of messages; amendment of Q code signals.	2 December 1960 1 April 1961 1 July 1961
38	Ordinary Administrative Radio Conference (OARC-1959)	Alignment of the provisions in Annex 10 with the related provisions of the Radio Regulations of the International Telecommunication Union (ITU).	20 January 1961 1 June 1961 1 July 1961
39	ICAO Panel of Teletypewriter Specialists (TTP)	Simplification of communication procedures for diversion routing, clarification of the application of ICAO two-letter abbreviations used in the addresses of messages and communication procedures concerning interstation co-operation.	26 June 1961 1 December 1961 1 January 1962
40	Seventh Session of the Communications Division	General updating and amendment of equipment and systems; radio frequencies and procedures.	5 April 1963 1 August 1963 1 November 1963
41	PANS-MET (Doc 7605)	Amendment of the Q code signals QFE, QFF and QNH to permit the transmission of altimeter settings in units of millibars or tenths of a millibar.	4 June 1963 1 October 1963 1 January 1964
42	Fourth Meeting of the Meteorological Telecommunications Network, Europe (MOTNE) Development/ Implementation Panel; Seventh Session of the Communications Division; and proposals by the Federal Republic of Germany, the United Kingdom and the United States	Non-typing or switching signals on the AFTN; new guidance material on ILS course structures and their evaluation; guidance material on ILS course structure and on the more important communication terms of specialized meaning and their definitions; the deletion of Part IV of the Annex as a consequence of the establishment of a new abbreviations and codes document; departure messages and guidance material on the monitoring of SSR.	25 March 1964 1 August 1964 1 January 1965

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
43	Seventh Session of the Communications Division	Amendments concerning the performance of ILS facilities, Category I and Category II.	23 June 1964 1 November 1964 1 February 1965
44	Seventh Session of the Communications Division; Fifth Meeting of the ICAO Panel of Teletypewriter Specialists; Rules of the Air, Air Traffic Services and Operations Division; Procedures for Air Navigation Services — Radiotelephony Procedures (Doc 7181)	Breakdown of Annex 10 into two volumes, Volume I (First Edition) containing Part I — Equipment and Systems, and Part II — Radio Frequencies, and Volume II (First Edition) containing Communications Procedures. Changes in the provisions regarding the action to be taken in the case of communications failure and in the case of transfer of communications watch from one radio frequency to another; provisions relating to teletypewriter procedures; deletion of the radiotelephony procedures in the aeronautical mobile service, except for certain basic provisions of the distress procedures.	31 May 1965 1 October 1965 10 March 1966
45	Fourth Air Navigation Conference; Sixth Meeting of the Panel of Teletypewriter Specialists	Specification of the technical characteristics for VHF survival radio equipment and introduction of the concept of the "ILS reference datum" in lieu of the "ILS reference point"; a number of AFTN technical provisions related to the progressive automation of the AFTN.	12 December 1966 12 April 1967 24 August 1967
46	Fifth Meeting of the ATC Automation Panel	Definitions and technical provisions relating to ATS message transmission on direct or omnibus channels.	7 June 1967 5 October 1967 8 February 1968
47	Communications/ Operations Divisional Meeting	Updating or expansion of practically every major specification. Of special importance are the changes to the ILS and SSR specifications; the introduction of a system specification for Loran-A; the expanded guidance material on the deployment of VHF communications frequencies and specification, for the first time, of the airborne elements of ADF, VHF and HF SSB Communications Systems.	11 December 1967 11 April 1968 22 August 1968
48	Communications/ Operations Divisional Meeting; Fifth Air Navigation Conference	New method of prescribing VOR/DME coverage; provisions regarding the availability of information on the operational status of radio navigation aids, regarding secondary power supplies of radio navigation and communication systems as well as guidance on power supply switch-over times for radio aids used in the vicinity of aerodromes.	23 January 1969 23 May 1969 18 September 1969
49	First Meeting of the Automated Data Interchange Systems Panel; Sixth Air Navigation Conference	Introduction of a 7-unit code for data interchange at medium signalling rates, the medium signalling rates to be used and the types of transmission and modulation for each of them; provisions concerning the secondary surveillance radar ground equipment to ensure immediate recognition of Codes 7600 and 7700 and provisions concerning the use of Code 2000 on Mode A.	1 June 1970 1 October 1970 4 February 1971

Amendment	*Source(s)*	*Subject(s)*	*Adopted* *Effective* *Applicable*
50	Second Meeting of the Automated Data Interchange Systems Panel; Air Navigation Commission Study on Regional Air Navigation Meeting recommendations of world-wide applicability; Fourth Meeting of the All Weather Operations Panel	Introduction of the term "Hertz (Hz)" in place of the term "cycles per second (c/s)" as the unit of frequency for electric and radio-technical matters; definition for data signalling rate, the extension of signalling rates to 9600 bits/second and some explanatory provisions related to the 7-unit coded character set; provisions concerning the pre-flight checking of VOR airborne equipment; definitions for "ILS Point D" and "ILS Point E" and some changes in the provisions relating to the specification for ILS and en-route VHF marker beacons.	24 March 1972 24 July 1972 7 December 1972
51	Third Meeting of the Automated Data Interchange Systems Panel; Third Meeting of the Obstacle Clearance Panel	Technical provisions relating to international ground-ground data interchange; guidance material concerning the lateral placement of the glide path antenna in relation to Annex 14 provisions on obstacle limitation surfaces and objects on strips for runways.	11 December 1972 11 April 1973 16 August 1973
52	Seventh Air Navigation Conference	New Standard relating to an emergency locator beacon — aircraft (ELBA); provision for additional localizer and glide path frequency pairs, and the introduction of 25 kHz channel spacing in the VHF band of the International Aeronautical Mobile Service; introduces refinements to the specifications for ILS, SSR and VOR, and extends the protection dates for ILS, DME and VOR from 1975 to 1985.	31 May 1973 1 October 1973 23 May 1974
53	Assembly Resolutions A17-10 and A18-10	Provisions relating to practices to be followed in the event that an aircraft is being subjected to unlawful interference.	7 December 1973 7 April 1974 23 May 1974
54*	Fourth Meeting of the Automated Data Interchange Systems Panel	New Attachment G to Part I of Volume I containing guidance material for ground-ground data interchange over data links at medium and higher signalling rates, and the insertion of cross references in Volume I, Part I, Chapter 4, 4.12.	17 June 1974 — —
55	Fifth Meeting of the All Weather Operations Panel; Second Meeting of the Review of the General Concept of Separation Panel; Air Navigation Working Group on Regional Plans; Seventh Air Navigation Conference	Technical specifications and guidance material for localizer and glide path components of the ILS; guidance material in respect of mandatory change-over points for VOR-defined ATS routes; alignment of the implementation provisions for ILS with those of other radio navigation aids; required geographic separation between ILS facilities and provisions concerning use of the VHF emergency channel (121.5 MHz) in the event of interception of aircraft.	4 February 1975 4 June 1975 9 October 1975
56	Correspondence	Designation of SSR Code 7500 for use in the event of unlawful interference.	12 December 1975 12 April 1976 12 August 1976
57	Asia/Pacific Regional Air Navigation Meeting	Provision of, and maintenance of guard on the VHF frequency 121.5 MHz.	16 June 1976 16 October 1976 6 October 1977

* Did not affect any Standards or Recommended Practices.

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
58	A study by the ANC of threshold wheel clearance; Sixth Meeting of the Automated Data Interchange Systems Panel; Proposal by France; Proposal by IFALPA	Introduction of tables of code conversion between the International Telegraph Alphabet No. 2 and the 7-unit coded character set; modification of the frame check sequence algorithm used for error checking in automated data interchange; amendment of material related to the ILS reference datum, introduction of new material related to the possibility of interference from spurious radiations in the LF/MF band and amendment to the guidance material in Attachments C and G to Part I.	23 and 27 June 1977 27 October 1977 23 February 1978
59	Ninth Air Navigation Conference; An ANC study of frangibility requirements emanating from Rec. 3/5 of the Third Meeting of the Obstacle Clearance Panel; Communications Divisional Meeting (1976)	Transfer of the SSR Mode B to an unassigned status; cross-reference to the provisions of Annex 14 concerning frangibility criteria for the navigational facilities on operational areas; cross-reference to the provisions of Annex 11 concerning the determination of VOR accuracy and change-over point; introduction of Attachment C to Part II, dealing with Guiding Principles for Long Distance Operational Control Communications.	14 December 1977 14 April 1978 10 August 1978
60	Sixth Meeting of the All Weather Operations Panel	Change of a preferred ILS glide path angle from 2.5 degrees to 3 degrees.	4 December 1978 4 April 1979 29 November 1979
61	Seventh Meeting of the Automated Data Interchange Systems Panel; All Weather Operations Divisional Meeting (1978); Communications Divisional Meeting (1978)	Introduction of a new series of marginal serial numbers in use by the International Telecommunication Union (ITU) and clarification of the term "Radio Regulations"; change to the definition of the Aeronautical Fixed Telecommunication Network (AFTN); change of the ILS protection date to 1995; addition of information related to the Microwave Landing System (MLS); changes in the radio frequency provisions related to the Final Acts of the ITU World Administrative Radio Conference (WARC) 1978; changes in the provisions related to the introduction of single sideband classes of emission into the high frequency (HF) aeronautical mobile service; clarification of symbols permitted with the 7-unit coded character set; change from single numbered to double numbered code and byte independent data link control procedures; introduction of new material related to character oriented data link control procedures; changes to the definition of operational control communications.	10 December 1979 10 April 1980 27 November 1980
62	Eighth Meeting of the Automated Data Interchange Systems Panel; Eighth Meeting of the All Weather Operations Panel; ANC study related to the interception of civil aircraft; recommendation of the Secretariat related to the protection date for VOR and DME	Changes to the protection date provisions of VOR and DME; changes and additions to the material related to ILS airborne equipment criteria and criteria on geographic separation of VOR/ILS facilities; addition of material related to the continuous check of channel condition and the use of controlled circuit protocols; changes to the provisions to make the 7-unit coded character set identical to the International Reference Version of International Alphabet No. 5; addition of provisions related to the use of character parity on CIDIN links; addition to the provisions related to character oriented data link control procedures; changes to the provisions related to VHF communication in the event of interception.	14 December 1981 14 April 1982 25 November 1982

Amendment	Source(s)	Subject(s)	Adopted Effective Applicable
63	Recommendations of the ANC relating to the assignment of an air-to-air VHF frequency at the request of IFALPA; recommendations of the Secretariat related to the depletion of the SELCAL codes; Accident Prevention and Investigation Divisional Meeting (1979); COM Divisional Meeting (1981)	Changes and additions to the material related to frequencies above 30 MHz used for particular functions to provide for an air-to-air VHF communications channel; addition of material related to the addition of new RED SELCAL tones; changes and additions to the material related to radar characteristics to provide for the recording and retention of radar data; extensive changes and additions to Chapters 1, 2, 3, 4, 5, 6 and Appendix A with respect to ILS, NDB, DME, MLS, radioteletype, VHF and HF communications, survival radio equipment and emergency locator beacons.	13 December 1982 13 April 1983 24 November 1983
64		Volume II only	
65	Recommendations of the ANC relating to the protection date of aeronautical mobile VHF communications equipment operating on 25 kHz channel spacing at the request of the Kingdom of the Netherlands; recommendations of the Secretariat related to harmful interference to aeronautical frequency bands from external sources, and related to switching and signalling over aeronautical voice circuits; recommendations of the ANC relating to SPI pulse in SSR Mode C at the request of the United Kingdom; Ninth Meeting of the All Weather Operations Panel; Tenth Meeting of the Automated Data Interchange Systems Panel	Changes to the material related to the protection date of aeronautical mobile VHF communications equipment operating on 25 kHz channel spacing; changes and additions to the material relating to harmful interference to aeronautical frequency bands from external sources; addition of material relating to switching and signalling over aeronautical voice circuits; changes to material relating to SSR SPI pulse transmission; extensive changes to Chapters 3, 4 and Attachments C, G and H with respect to ILS, DME and CIDIN.	6 December 1984 6 April 1985 21 November 1985

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

Note.— The terms "height", "altitude" and "elevation" have been used throughout this Annex in accordance with the definitions of those terms approved by Council at the 13th Meeting of its Twelfth Session and the term "pressure-altitude" in accordance with the definition approved by Council at the 11th Meeting of its Thirteenth Session; these definitions are as follows:

Height:

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

Note.— The datum may be specified either in the text or in an explanatory note in the publication concerned.

2) The vertical dimension of an object.

Note.— The term "height" may also be used in a figurative sense for a dimension other than vertical, e.g. the height of a letter or a figure on a runway.

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

Elevation. The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

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

ANNEX 10 — VOLUME I

PART I — EQUIPMENT AND SYSTEMS

Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union.

Note 2.— This Part of Annex 10 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*).*

CHAPTER 1. DEFINITIONS

When the following terms are used in Part I of this Annex, they have the following meanings:

Aeronautical fixed circuit. A circuit forming part of the aeronautical fixed service.

Aeronautical fixed service (AFS). A telecommunication service between specified fixed points provided primarily for the safety of air navigation and for the regular, efficient and economical operation of air services.

Aeronautical fixed telecommunication network (AFTN). A world-wide system of aeronautical fixed circuits provided, as part of the aeronautical fixed service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

Aeronautical fixed telecommunication network circuit. A circuit forming part of the AFTN.

AFTN group. Three or more radio stations in the aeronautical fixed telecommunications network exchanging communications on the same radio frequency.

A2A emission. Telegraphy by the on/off keying of an amplitude modulated audio frequency or audio frequencies,

or by the on/off keying of the modulated emission (*special case:* an unkeyed emission amplitude modulated).

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.

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

ILS reference datum. A point at a specified height located vertically above the intersection of the runway centre line and the threshold and through which the downward extended straight portion of the glide path passes.

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.

Touchdown. The point where the predetermined 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. RADIO NAVIGATION AIDS

2.1 Aids to final approach and landing

2.1.1 The standard non-visual aids to final approach and landing shall be the instrument landing system (ILS) conforming to the Standards contained in Part I, 3.1, and the microwave landing system (MLS) conforming to the Standards contained in Part I, 3.11.

Note 1.— It is intended that transition from ILS to MLS be in accordance with an ICAO transition plan.

Note 2.— It is intended that, wherever an aid conforming to the Standards in Part I, 3.1 has been installed, no change in, or addition to, those Standards will require the replacement of such equipment before 1 January 1995. It is also intended that the ILS protection date be re-examined before 1 January 1985.

Note 3.— During the ILS protection period, it is intended that MLS conforming to the Standards of Part I, 3.11 may be installed:

a) where for operational, technical, or economic reasons, an ILS service cannot be provided prior to the ILS protection date of 1 January 1995;

b) in addition to ILS, provided that at least the existing level of ILS service is retained, unless otherwise determined by regional air navigation agreements in cases where it is no longer economic to retain the existing level of ILS within the five years prior to the ILS protection date.

Note 4.— The locations at which ILS and/or MLS installations are required are normally established on the basis of regional air navigation agreements.

Note 5.— An ILS installation conforming to the Standard contained in Part I, 3.1 may be retained after the ILS protection date as a non-visual aid to final approach and landing on the basis of regional air navigation agreements.

Note 6.— Since visual reference is essential for the final stages of approach and landing, the installation of ILS or MLS does not obviate the need for visual aids to approach and landing in conditions of low visibility.

2.1.1.1 When an ILS is to be provided, the performance category required shall correspond at least to the category of precision approach runway to be served and shall be chosen from those defined and specified in Part I, 3.1.

Note.— Information on operational objectives associated with Performance Categories is given in Section 2 of Attachment C to Part I.

2.1.2 Differences in ILS and MLS installations in any respect from the Standards of Part I, 3.1 and 3.11 respectively shall be published in NOTAM, manuals or other documents used for the dissemination of such aeronautical information.

2.1.2.1 Non-visual aids to final approach and landing that do not conform:

a) to the Standards in Part I, 3.1.2.1, 3.1.2.2 and 3.1.7.1 a) shall not be described by the term ILS;

b) to the Standards in Part I, 3.11.3 shall not be described by the term MLS.

2.1.3 Wherever there is installed a non-visual aid to final approach and landing 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 NOTAM, manuals or other documents used for the dissemination of such aeronautical information.

2.1.4 **Recommendation.—** *A precision approach radar system conforming to the Standards contained in Part I, 3.2 and equipment for two-way communication with aircraft, together with facilities for the efficient co-ordination of these elements with air traffic control, should be installed and operated as a supplement to the ILS wherever:*

a) air traffic control will be materially assisted by such installation in the landing of aircraft intending to use the ILS; and

b) the accuracy or expedition of final approaches or the facilitation of approaches by aircraft not equipped to use the ILS will be materially aided by such installation.

2.1.4.1 **Recommendation.—** *A precision approach radar system should be installed and maintained in operation at airfields where ILS is required under the provision of 2.1.1.1 above but where an ILS installation is technically impracticable.*

2.1.4.2 Only the precision approach radar element (PAR) of the precision approach radar system conforming to the Standards contained in Part I, 3.2.3, together with the equipment and facilities prescribed in 2.1.4 above, shall need to be installed when it is determined that the surveillance radar element (SRE), associated with the precision approach radar system, is not necessary to meet the requirements of air traffic control for the handling of aircraft intending to use the ILS.

Note.— The SRE is not considered, in any circumstances, a satisfactory alternative to the precision approach radar system.

2.1.4.3 **Recommendation.**— *Although SRE is not considered a satisfactory alternative to the precision approach radar system, an SRE conforming to the Standards contained in Part I, 3.2.4 and equipment for two-way communication with aircraft should be installed and operated for:*

a) the assistance of air traffic control in handling aircraft intending to use the ILS;

b) surveillance radar approaches and departures.

2.1.5 **Recommendation.**— *The ILS should be supplemented 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 course line.*

Note.— The following sources of guidance have been used for such purposes. Appropriate guidance with respect to a) and b) is contained in Attachment C to Part I, 2.12:

a) a suitably located VHF omnidirectional radio range (VOR) or equivalent;

b) a locator or locators conforming with the specifications in 3.4 of Part I or a suitably located non-directional radio beacon (NDB);

c) a suitably located DME providing continuous distance information during the approach and missed approach phases of flight.

2.1.6 **Recommendation.**— *Where necessary, the MLS should be supplemented 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 selected MLS approach path.*

2.2 Short-distance aids

2.2.1 In localities and along routes where conditions of traffic density and low visibility necessitate a ground based short-distance radio aid to navigation for the efficient exercise of air traffic control, or where such short-distance aid is required for the safe and efficient conduct of aircraft operations, the standard aid shall be the VHF omnidirectional radio range (VOR) of the CW phase comparison type conforming to the Standards contained in Part I, 3.3.

Note 1.— It is not intended that short-distance radio aids to navigation provided in accordance with 2.2.1 above should be required primarily to perform the function of a long-distance navigation aid.

Note 2.— It is intended that, wherever a VOR conforming to the Standard in 2.2.1 above has been installed, no change in, or addition to, that Standard will require the replacement of such equipment before 1 January 1995.

2.2.1.1 **Recommendation.**— *Means should be provided for the pre-flight checking of VOR airborne equipment at aerodromes regularly used by international air traffic.*

Note.— Guidance material on the pre-flight checking of VOR airborne equipment is contained in Attachment E to Part I.

2.2.2 At localities where for operational reasons, or because of air traffic control reasons such as air traffic density or proximity of routes, there is a need for a more precise navigation service than that provided by VOR, distance measuring equipment (DME) (conforming to the Standards in Part I, 3.5) shall be installed and maintained in operation as a complement to VOR.

2.2.2.1 DME/N equipment first installed after 1 January 1989 shall also conform to the Standards in Part I, 3.5 denoted by ‡.

2.2.2.2 **Recommendation.**— *The Standards marked with ‡ should be treated as recommendations until the operative date given in 2.2.2.1 above.*

Note.— It is intended that, wherever a DME conforming to the Standard in 2.2.2 above has been installed, no change in, or addition to, that Standard will require the replacement of such equipment before 1 January 1995.

2.2.3 DME/W conforming to the Standard contained in Part I, 3.5.4.1.3 f) shall be installed only on the basis of regional agreement.

Note.— There are likely to be locations at which DME/W may be usefully installed, especially for national use. Co-ordination within the Region concerned, or between Regions, is needed to avoid possible interference and to assist in the maintenance of a current and complete frequency allocation plan.

2.2.3.1 **Recommendation.**— *There should be no new installations of DME/W after 1 January 1987.*

2.3 Radio beacons

2.3.1 Non-directional radio beacons (NDB)

2.3.1.1 An NDB conforming to the Standards in Part I, 3.4 shall be installed and maintained in operation at a locality where an NDB, in conjunction with direction-finding equipment in the aircraft, fulfils the operational requirement for a radio aid to navigation.

2.3.2 En-route VHF marker beacons (75 MHz)

2.3.2.1 **Recommendation.**— *Where a VHF marker beacon is required to mark a position on any air route, a fan marker beacon conforming to the Standard contained in Part I, 3.6 should be installed and maintained in operation.*

Note.— This recommendation does not preclude the use of fan marker beacons at points other than on an air route as, for example, an aid to descent under IFR conditions.

2.3.2.2 **Recommendation.**— *Where a VHF marker beacon is required to mark the position of a radio navigation aid giving directional or track guidance, a Z marker conforming to the Standard in Part I, 3.6 should be installed and maintained in operation.*

2.4 Long-distance aids

2.4.1 Until such time as a new station-referenced long-distance radio navigational aids system is agreed to be necessary to permit a better navigational capability and is implemented, or until it is shown that a long-distance navigation system based on self-contained aids is meeting the operational requirements, the facilities Loran-A, Consol and NDB presently installed and providing important coverage over certain vital oceanic areas and land masses shall be retained, and these systems extended and supplemented as may be necessary to meet air traffic requirements.

Note 1.— "Station-referenced" aids are understood to include "ground-referenced" or "satellite-referenced" aids.

"Self-contained" aids are understood to include "Doppler radar", "inertial navigation" and "celestial navigation", or combinations thereof.

Note 2.— Information regarding the operational requirements for long-distance navigation is contained in 2.4 of Attachment A to Part I.

2.5 Secondary surveillance radar (SSR)

2.5.1 When SSR is installed and maintained in operation as an aid to air traffic services, it shall conform with the provisions of Part I, 3.8 unless otherwise specified in this 2.5.

2.5.2 Interrogation modes (ground-to-air)

2.5.2.1 Interrogation for air traffic services shall be performed on the modes described in Part I, 3.8.4.3. The primary use of each mode shall be as follows:

1) *Mode A* — to initiate transponder response for identification and tracking.

2) *Mode B* — for future expansion of the system to satisfy operational requirements that may be agreed by ICAO.

3) *Mode C* — to initiate transponder responses for automatic pressure-altitude transmission.

4) *Mode D* — for future expansion of the system to satisfy operational requirements that may be agreed by ICAO.

Note 1.— If future extension of the use of SSR requires the use of an additional Mode, it is intended that Mode D should be used ahead of Mode B (see 4.8.1.2 of Attachment B to Part I).

Note 2.— Attachment B to Part I contains guidance relating to technical provision for possible future use of Modes B and D.

2.5.2.1.1 **Recommendation.**— *In order to enhance system reliability and reduce system complexity, the SSR system for air traffic service should be operated on a minimum number of modes. This indicates that a single mode should be used for each functional requirement.*

2.5.2.1.2 **Recommendation.**— *Administrations should co-ordinate with appropriate national and international authorities those implementation aspects of the SSR system which will permit its optimum use.*

Note 1.— Section 3 of Attachment B to Part I contains guidance on the factors affecting optimum use of SSR.

Note 2.— In order to permit the efficient operation of ground equipment designed to eliminate interference from unwanted aircraft transponder replies to adjacent interrogators (defruiting equipment), States may need to develop co-ordinated plans for the assignment of pulse recurrence frequencies (PRF) to SSR interrogators.

2.5.2.2 Mode A interrogation at least shall be provided.

2.5.2.2.1 **Recommendation.**— *In areas where automatic pressure-altitude transmission capability is necessary to enhance the effectiveness of the ATC system, Mode C should also be provided.*

2.5.2.3 *Side-lobe suppression control interrogation*

2.5.2.3.1 Side-lobe suppression shall be provided in accordance with the provisions of Part I, 3.8.4 and 3.8.5, as soon as practicable, and by a date not later than 1 January 1970.

2.5.3 Airborne transponder reply modes (air-to-ground)

2.5.3.1 Airborne transponders shall respond to Mode A interrogations. Where the need for Mode C automatic pressure-altitude transmission capability within a specified airspace has been determined, transponders, when used within the airspace concerned, shall also respond to Mode C interrogations with that capability.

Note.— A State, if it has appropriate ground capability and considers full Mode C airborne capability within part or all of its airspace to be essential for the safety and regularity of air navigation, may itself determine the need for Mode C automatic pressure-altitude transmission therein. It is, however, intended that this need would ordinarily be determined by regional air navigation agreement which would specify the airspaces and aircraft operations concerned, as well as the time scale for implementation.

2.5.4 Reply codes (information pulses)

2.5.4.1 Transponders shall generate reply codes conforming to the characteristics given in Part I, 3.8.6.2.

Note.— It is not intended that this Standard should apply to transponders fitted in aircraft used exclusively in areas where not more than 64 codes are used.

2.5.4.1.1 **Recommendation.**— *The specific codes to be applied should be agreed between the Administrations concerned, taking into account other users of the system.*

2.5.4.1.2 **Recommendation.**— *All ground equipment should be capable of recognizing the A, B, C and D information pulses prescribed in Part I, 3.8.6.2, in order to permit optimum utilization of 4 096-reply code capability.*

Note.— This recommendation does not require the provision of more than 64-code capability in areas where there is no requirement. Its intent is to encourage the provision of capability to recognize A, B, C and D information pulses in new facilities, and in existing facilities where the use of 64-code capability might restrict the use of 4 096-code capability.

2.5.4.2 Code 7700 shall be used on Mode A to provide recognition of an aircraft in an emergency.

2.5.4.3 Code 7600 shall be used on Mode A to provide recognition of an aircraft with radiocommunication failure.

2.5.4.4 Code 7500 shall be used on Mode A to provide recognition of an aircraft which is being subjected to unlawful interference.

2.5.4.5 **Recommendation.**— *Appropriate provisions should be made in the ground equipment to ensure immediate recognition of Codes 7500, 7600 and 7700.*

Note.— Paragraph 2.1.2 of Attachment B to Part I gives some guidance on possible arrangements associated with 2.5.4.2, 2.5.4.3 and 2.5.4.5 above.

2.5.4.6 **Recommendation.**— *Code 0000 should be reserved for allocation subject to regional agreement, as a general purpose code.*

2.5.4.7 **Recommendation.**— *Code 2000 should be reserved on Mode A for allocation, subject to regional air navigation agreement, for use where there is a need for an aircraft to select a code without ATC instruction before entering an area of secondary radar coverage.*

2.6 Distance measuring — general

2.6.1 **Recommendation.**— *If a distance measuring facility is installed and maintained in operation for any radio navigational purpose additional to that specified in 2.2.2 above, it should conform to the specification in Part I, 3.5.*

2.7 Ground and flight testing

2.7.1 Radio navigation aids of the types covered by the specifications in Part I, Chapter 3, of this Annex 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 some ICAO standard facilities is contained in Attachment C to Part I and in Doc 8071.

2.8 Provision of information on the operational status of radio navigation aids

2.8.1 Aerodrome control towers and units providing approach control service shall be provided without delay with information on the operational status of radio navigation aids essential for approach, landing and take-off at the aerodrome(s) with which they are concerned.

2.9 Secondary power supply for radio navigation aids and communication systems

2.9.1 Radio navigation aids and ground elements of communication systems of the type specified in Volume I, Part I of Annex 10 shall be provided with suitable power supplies and means to ensure continuity of service appropriate to the needs of the service provided.

Note.— Guidance material on this subject is contained in Section 8 of Attachment C to Part I.

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

Note.— Specifications concerning the siting and construction of equipment and installations on operational areas aimed at reducing the hazard to aircraft to a minimum are contained in Annex 14, Chapter 8.

3.1 Specification for ILS

3.1.1 Definitions

Angular displacement sensitivity. The ratio of measured DDM to the corresponding angular displacement from the appropriate reference line.

Back course sector. The course sector which is situated on the opposite side of the localizer from the runway.

Course line. The locus of points nearest to the runway centre line in any horizontal plane at which the DDM is zero.

Course sector. A sector in a horizontal plane containing the course line and limited by the loci of points nearest to the course line at which the DDM is 0.155.

DDM — Difference in depth of modulation. The percentage modulation depth of the larger signal minus the percentage modulation depth of the smaller signal, divided by 100.

Displacement sensitivity (localizer). The ratio of measured DDM to the corresponding lateral displacement from the appropriate reference line.

Facility Performance Category I — ILS. An ILS which provides guidance information from the coverage limit of the ILS to the point at which the localizer course line intersects the ILS glide path at a height of 60 m (200 ft) or less above the horizontal plane containing the threshold.

Note.— This definition is not intended to preclude the use of Facility Performance Category I — ILS below the height of 60 m (200 ft), with visual reference where the quality of the guidance provided permits, and where satisfactory operational procedures have been established.

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

Facility Performance Category III — ILS. An ILS which, with the aid of ancillary equipment where necessary, provides guidance information from the coverage limit of the facility to, and along, the surface of the runway.

Front course sector. The course sector which is situated on the same side of the localizer as the runway.

Half course sector. The sector, in a horizontal plane containing the course line and limited by the loci of points nearest to the course line at which the DDM is 0.0775.

Half ILS glide path sector. The sector in the vertical plane containing the ILS glide path and limited by the loci of points nearest to the glide path at which the DDM is 0.0875.

ILS continuity of service. That quality which relates to the rarity of radiated signal interruptions during any approach. The level of continuity of service of the localizer or the glide path is expressed in terms of the probability of not losing the radiated guidance signals.

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

ILS glide path angle. The angle between a straight line which represents the mean of the ILS glide path and the horizontal.

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

Note.— The ILS glide path sector is located in the vertical plane containing the runway centre line, and is divided by the radiated glide path in two parts called upper sector and lower sector, referring respectively to the sectors above and below the glide path.

ILS integrity. That quality which relates to the trust which can be placed in the correctness of the information supplied by the facility. The level of integrity of the localizer or the glide path is expressed in terms of the probability of not radiating false guidance signals.

ILS Point "A". A point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 7.5 km (4 NM) from the threshold.

ILS Point "B". A point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 1 050 m (3 500 ft) from the threshold.

ILS Point "C". A point through which the downward extended straight portion of the nominal ILS glide path passes at a height of 30 m (100 ft) above the horizontal plane containing the threshold.

ILS Point "D". A point 4 m (12 ft) above the runway centre line and 900 m (3 000 ft) from the threshold in the direction of the localizer.

ILS Point "E". A point 4 m (12 ft) above the runway centre line and 600 m (2 000 ft) from the stop end of the runway in the direction of the threshold.

Note.— See Attachment C to Part I, Figure C-1.

ILS reference datum (Point "T"). A point at a specified height located vertically above the intersection of the runway centre line and the threshold and through which the downward extended straight portion of the ILS glide path passes.

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

Two-frequency localizer system. A localizer system in which coverage is achieved by the use of two independent radiation field patterns spaced on separate carrier frequencies within the particular localizer VHF channel.

3.1.2 Basic requirements

3.1.2.1 The ILS shall comprise the following basic components:

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

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

c) VHF marker beacons, associated monitor systems, remote control and indicator equipment, except as provided in 3.1.7.6.6 below.

Note.— It is intended that the air traffic services unit involved in the control of aircraft on the final approach be one of the designated control points receiving without delay information on the operational status of the ILS as derived from the monitors.

3.1.2.1.1 Facility Performance Categories II and III — ILS also shall comprise remote indicator and control equipment, which shall provide indications at designated remote control points of the operational status of all ILS ground system components.

Note.— It is intended that the air traffic system is likely to call for additional provisions which may be found essential for the attainment of full operational Category III capability, e.g. to provide additional lateral and longitudinal guidance during the landing roll-out, and taxiing, and to ensure enhancement of the integrity and reliability of the system.

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

3.1.2.3 The localizer and glide path components specified in 3.1.2.1 a) and b) above which form part of a Facility Performance Category I — ILS shall comply at least with the Standards in 3.1.3 and 3.1.5 below respectively, excepting those in which application to Facility Performance Category II — ILS is prescribed.

3.1.2.4 The localizer and glide path components specified in 3.1.2.1 a) and b) above which form part of a Facility Performance Category II — ILS shall comply with the Standards applicable to these components in a Facility Performance Category I — ILS, as supplemented or amended by the Standards in 3.1.3 and 3.1.5 below in which application to Facility Performance Category II — ILS is prescribed.

3.1.2.5 The localizer and glide path components and other ancillary equipment specified in 3.1.2.1.1 above, which form part of a Facility Performance Category III — ILS, shall otherwise comply with the Standards applicable to these components in Facility Performance Categories I and II — ILS, except as supplemented by the Standards in 3.1.3 and 3.1.5 below in which application to Facility Performance Category III — ILS is prescribed.

3.1.2.6 To ensure an adequate level of safety, the ILS shall be so designed and maintained that the probability of operation within the performance requirements specified is of a high value, consistent with the category of operational performance concerned.

Note.— The specifications for Facility Performance Categories II and III — ILS are intended to achieve the highest degree of system integrity, reliability and stability of operation under the most adverse environmental conditions to be encountered. Guidance material to achieve this objective in Categories II and III operations is given in 2.8 of Attachment C to Part I.

3.1.2.7 At those locations where two separate ILS facilities serve opposite ends of a single runway, an interlock shall ensure that only the localizer serving the approach direction in use shall radiate, except where the localizer in operational use is Facility Performance Category I — ILS and no operationally harmful interference results.

3.1.2.7.1 **Recommendation.—** *At those locations where two separate ILS facilities serve opposite ends of a single runway and where a Facility Performance Category I — ILS is to be used for auto-coupled approaches and landings in visual conditions an interlock should ensure that only the localizer serving the approach direction in use radiates, providing the other localizer is not required for simultaneous operational use.*

Note.— If both localizers radiate there is a possibility of interference to the localizer signals in the threshold region. Additional guidance material is contained in 2.1.9 and 2.13 of Attachment C to Part I.

3.1.2.7.2 At locations where ILS facilities serving opposite ends of the same runway or different runways at the same airport use the same paired frequencies, an interlock shall ensure that only one facility shall radiate at a time. When switching from one ILS facility to another, radiation from both shall be suppressed for not less than 20 seconds.

Note.— Additional guidance material on the operation of localizers on the same frequency channel is contained in 4.2.6 of Part II and 2.1.9 of Attachment C to Part I.

3.1.3 VHF localizer and associated monitor

Introduction.— The specifications of this 3.1.3 cover ILS localizers providing either positive guidance information over 360 degrees of azimuth, or providing such guidance only within a specified portion of the front coverage (see 3.1.3.7.4 below). Where ILS localizers providing positive guidance information in a limited sector are installed, information from some suitably located navigation aid, together with appropriate procedures, will generally be required to ensure that any misleading guidance information outside the sector is not operationally significant.

3.1.3.1 *General*

3.1.3.1.1 The radiation from the localizer antenna system shall produce a composite field pattern which is amplitude modulated by a 90 Hz and a 150 Hz tone. The radiation field pattern shall produce a course sector with one tone predominating on one side of the course and with the other tone predominating on the opposite side.

3.1.3.1.2 When an observer faces the localizer from the approach end of a runway, the depth of modulation of the radio frequency carrier due to the 150 Hz tone shall predominate on his right hand and that due to the 90 Hz tone shall predominate on his left hand.

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

3.1.3.2 *Radio frequency*

3.1.3.2.1 The localizer shall operate in the band 108 MHz to 111.975 MHz. Where a single radio frequency carrier is used, the frequency tolerance shall not exceed plus or minus 0.005 per cent. Where two radio frequency carriers 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 5 kHz nor more than 14 kHz.

3.1.3.2.2 The emission from the localizer shall be horizontally polarized. The vertically polarized component of the radiation on the course line shall not exceed that which corresponds to a DDM error of 0.016 when an aircraft is positioned on the course line and is in a roll attitude of 20 degrees from the horizontal.

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

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

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

3.1.3.3 *Coverage*

3.1.3.3.1 The localizer shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation within the localizer and glide path coverage sectors. The localizer coverage sector shall extend from the centre of the localizer antenna system to distances of:

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

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

18.5 km (10 NM) outside of plus or minus 35 degrees if coverage is provided;

except that, where topographical features dictate or operational requirements permit, the limits may be reduced to 33.3 km (18 NM) within the plus or minus 10-degree sector and 18.5 km (10 NM) within the remainder of the coverage when alternative navigational facilities provide satisfactory coverage within the intermediate approach area. The localizer signals shall be receivable at the distances specified at and above a height of 600 m (2 000 ft) above the elevation of the threshold, or 300 m (1 000 ft) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher. Such signals shall be receivable, to the distances specified, up to a surface extending outward from the localizer antenna and inclined at 7 degrees above the horizontal.

3.1.3.3.2 In all parts of the coverage volume specified in 3.1.3.3.1 above, other than as specified in 3.1.3.3.2.1, 3.1.3.3.2.2 and 3.1.3.3.2.3 below, the field strength shall be not less than 40 microvolts per metre (minus 114 dBW/m^2).

Note.— This minimum field strength is required to permit satisfactory operational usage of ILS localizer facilities.

3.1.3.3.2.1 For Facility Performance Category I localizers, the minimum field strength on the ILS glide path and within the localizer course sector from a distance of 18.5 km (10 NM) to a height of 60 m (200 ft) above the horizontal plane containing the threshold shall be not less than 90 microvolts per metre (minus 107 dBW/m²).

3.1.3.3.2.2 For Facility Performance Category II localizers, the minimum field strength on the ILS glide path and within the localizer course sector shall be not less than 100 microvolts per metre (minus 106 dBW/m²) at a distance of 18.5 km (10 NM) increasing to not less than 200 microvolts per metre (minus 100 dBW/m²) at a height of 15 m (50 ft) above the horizontal plane containing the threshold.

3.1.3.3.2.3 For Facility Performance Category III localizers, the minimum field strength on the ILS glide path and within the localizer course sector shall be not less than 100 microvolts per metre (minus 106 dBW/m²) at a distance of 18.5 km (10 NM), increasing to not less than 200 microvolts per metre (minus 100 dBW/m²) at 6 m (20 ft) above the horizontal plane containing the threshold. From this point to a further point 4 m (12 ft) above the runway centre line, and 300 m (1 000 ft) from the threshold in the direction of the localizer, and thereafter at a height of 4 m (12 ft) along the length of the runway in the direction of the localizer, the field strength shall be not less than 100 microvolts per metre (minus 106 dBW/m²).

Note.— The field strengths given in 3.1.3.3.2.2 and 3.1.3.3.2.3 above are necessary to provide the signal-to-noise ratio required for improved integrity.

3.1.3.3.3 **Recommendation.—** *Above 7 degrees, the signals should be reduced to as low a value as practicable.*

Note 1.— The requirements in 3.1.3.3.1, 3.1.3.3.2.1, 3.1.3.3.2.2 and 3.1.3.3.2.3 above 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 2.2.2 and 2.2.4 of Attachment C to Part I.

3.1.3.3.4 When coverage is achieved by a localizer using two radio frequency carriers, one carrier providing a radiation field pattern in the front course sector and the other providing a radiation field pattern outside that sector, the ratio of the two carrier signal strengths in space within the front course sector to the coverage limits specified at 3.1.3.3.1 above shall not be less than 10 dB.

Note.— Guidance material on localizers achieving coverage with two radio frequency carriers is given in the Note to 3.1.3.11.2 below and in 2.7 of Attachment C to Part I.

3.1.3.4 *Course structure*

3.1.3.4.1 For Facility Performance Category I localizers, bends in the course line shall not have amplitudes which exceed the following:

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

3.1.3.4.2 For Facility Performance Categories II and III localizers, bends in the course line shall not have amplitudes which exceed the following:

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

Note 1.— The amplitudes referred to in 3.1.3.4.1 and 3.1.3.4.2 above are the DDMs due to bends as realized on the mean course line, when correctly adjusted.

Note 2.— Guidance material relevant to the localizer course structure is given in 2.1.4, 2.1.6 and 2.1.7 of Attachment C to Part I.

3.1.3.5 *Carrier modulation*

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

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

3.1.3.5.3 The following tolerances shall be applied to the frequencies of the modulating tones:

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

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

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

d) the total harmonic content of the 90 Hz tone shall not exceed 10 per cent; additionally, for Facility Performance Category III localizers, 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.

3.1.3.5.3.1 **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.*

3.1.3.5.3.2 For Facility Performance Category III localizers, the depth of amplitude modulation of the radio frequency carrier at the power supply frequency or its harmonics, or by other unwanted components, shall not exceed 0.5 per cent. Harmonics of the supply, or other unwanted noise components that may intermodulate with the 90 Hz and 150 Hz navigational tones or their harmonics to produce fluctuations in the course line, shall not exceed 0.05 per cent modulation depth of the radio frequency carrier.

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

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

b) for Facility Performance Category III localizers: 10 degrees,

of phase relative to the 150 Hz component, every half cycle of the combined 90 Hz and 150 Hz wave form.

Note 1.— The definition of phase relationship in this manner is not intended to imply a requirement to measure the phase within the half course sector.

Note 2.— Guidance material relative to such measurement is given at Figure C-6 of Attachment C to Part I.

3.1.3.5.3.4 With two-frequency localizer systems, 3.1.3.5.3.3 above 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 localizers: 20 degrees; and

b) for Category III localizers: 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 localizers: 20 degrees; and

2) for Category III localizers: 10 degrees,

of phase relative to 150 Hz.

3.1.3.5.3.5 Alternative two-frequency localizer systems that employ audio phasing different from the normal inphase conditions described in 3.1.3.5.3.4 above shall be permitted. In this alternative system, 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 3.1.3.5.3.4 above.

Note.— This is to ensure correct airborne receiver operation in the region away from the course line where the two carrier signal strengths are approximately equal.

3.1.3.5.3.6 **Recommendation.**— *The sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones should not exceed 95 per cent within the required coverage.*

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.

3.1.3.6 *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 above 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 above.

Note 3.— Guidance material on measurement of localizer course alignment is given in 2.1.4 of Attachment C to Part I.

3.1.3.7 *Displacement sensitivity*

3.1.3.7.1 The nominal displacement sensitivity within the half course sector at the ILS reference datum shall be 0.00145 DDM/m (0.00044 DDM/ft) 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 6 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 and 3.1.3.7.2 above 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 to Part I.

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

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.

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, navigational 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 above). 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 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 navigational components, or during maintenance or test transmissions, the identification signal shall be suppressed.

3.1.3.10 *Siting*

3.1.3.10.1 The localizer antenna system shall be located on the extension of 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 system shall have the minimum height necessary to satisfy the coverage requirements laid down in 3.1.3.3 above, and the distance from the stop end of the runway shall be consistent with safe obstruction clearance practices.

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 below, if any of the conditions stated in 3.1.3.11.2 below persists:

a) radiation to cease;

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

c) reversion to a lower category in the case of Facility Performance Categories II and III localizers where the reversion requirement exists.

Note.— It is intended that the alternative of reversion offered in 3.1.3.11.1 above may be used only if:

1) the safety of the reversion procedure has been substantiated; and

2) the means of providing information to the pilot on the change of category has adequate integrity.

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 less than 50 per cent of normal, provided the localizer continues to meet the requirements of 3.1.3.3, 3.1.3.4 and 3.1.3.5 above;

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 above;

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 above 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) above, 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 above.

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 above 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 above 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, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent change-over(s) to localizer equipment(s) 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 above 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 2.1.8 of Attachment C to Part I.

3.1.3.11.5 Any erroneous navigation signals on the carrier occurring during removal of navigation and identification components in accordance with 3.1.3.11.1 b) above shall be suppressed within the total periods allowed in 3.1.3.11.3.1 above.

Note.— To prevent hazardous fluctuations in the radiated signal, localizers employing mechanical modulation equipment may require suppression of navigation components during modulator rundown.

3.1.4 Interference immunity performance for ILS localizer receiving systems

3.1.4.1 After 1 January 1998, 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:

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

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

and

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

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 below.

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

3.1.4.2 After 1 January 1998, 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*
88-102	+ 15 dBm
104	+ 10 dBm
106	+ 5 dBm
107.9	– 10 dBm

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

Note.— Guidance material on immunity criteria to be used for the performance quoted in 3.1.4.1 and 3.1.4.2 above is contained in Attachment C to Part I, 2.2.10.

3.1.4.3 After 1 January 1995, all new installations of airborne ILS localizer receiving systems shall meet the provisions of 3.1.4.1 and 3.1.4.2 above.

3.1.4.4 **Recommendation.—** *Airborne ILS localizer receiving systems meeting the immunity performance standards of 3.1.4.1 and 3.1.4.2 above should be placed into operation at the earliest possible date.*

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 UHF glide path equipment should be capable of adjustment to produce a radiated glide path from 2 to 4 degrees with respect to the horizontal.*

3.1.5.1.2.1 **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.*

3.1.5.1.2.2 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 to Part I.

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 to Part I 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 to Part I.

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 above, the minimum field

strength within this coverage sector shall be 400 microvolts per metre (minus 95 dBW/m²). 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 2.2.5 of Attachment C to Part I.

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 to Part I.

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 ILS reference datum	0.023

Note 1.— The amplitudes referred to in 3.1.5.4.1 and 3.1.5.4.2 above 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 2.1.5 of Attachment C to Part I.

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 to Part I.

3.1.5.5.3.1 With two-frequency glide path systems, 3.1.5.5.3 above 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 inphase condition described in 3.1.5.5.3.1 above 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 above.

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

3.1.5.6 *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 above.*

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 to Part I.

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.

Note.— Explanatory material on ILS glide path adjustment and maintenance values appears at 2.1.5 of Attachment C to Part I.

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 below if any of the following conditions persist:

a) shift of the mean ILS glide path angle equivalent to more than 0.075 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, provided the glide path continues to meet the requirements of 3.1.5.3, 3.1.5.4 and 3.1.5.5 above;

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 above;

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 above 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 plus or minus 0.0375 θ;

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 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 above, 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 2.4.13 of Attachment C to Part I.

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 a), b), c), d), e) and f) of 3.1.5.7.1 above 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 above 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 period(s) of zero radiation, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent changeover(s) to glide path equipment(s) 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 above 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 2.1.8 of Attachment C to Part I.

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 Part II, 4.2:

Localizer (MHz)	*Glide path (MHz)*	*Localizer (MHz)*	*Glide path (MHz)*
108.1	334.7	109.5	332.6
108.15	334.55	109.55	332.45
108.3	334.1	109.7	333.2
108.35	333.95	109.75	333.05
108.5	329.9	109.9	333.8
108.55	329.75	109.95	333.65
108.7	330.5	110.1	334.4
108.75	330.35	110.15	334.25
108.9	329.3	110.3	335.0
108.95	329.15	110.35	334.85
109.1	331.4	110.5	329.6
109.15	331.25	110.55	329.45
109.3	332.0	110.7	330.2
109.35	331.85	110.75	330.05

Localizer (MHz)	*Glide path (MHz)*	*Localizer (MHz)*	*Glide path (MHz)*
110.9	330.8	111.5	332.9
110.95	330.65	111.55	332.75
111.1	331.7	111.7	333.5
111.15	331.55	111.75	333.35
111.3	332.3	111.9	331.1
111.35	332.15	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
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 re-assigned frequencies, conforming with 3.1.6.1 or 3.1.6.1.1 above as soon as practicable and may continue operating on their present assignments only until this re-assignment 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 above (see Part II, 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 3.1.7.6.6 below. 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 this 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 3.7.1 below.

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 below.

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 0.01 per cent and shall utilize horizontal polarization. As from 1 January 1985 all newly installed marker beacons shall have a frequency tolerance of plus or minus 0.005 per cent. After 1 January 1990 this provision applies for all marker beacons.

3.1.7.2.2 **Recommendation.—** *Marker beacons should operate with a frequency tolerance of plus or minus 0.005 per cent.*

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 above shall be 1.5 millivolts per metre (82 dBW/m^2). In addition, the field strength within the coverage area shall rise to at least 3.0 millivolts per metre (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 (82 dBW/m²).

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 2.10 of Attachment C to Part I.

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 above.*

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 2.2.2 of Attachment A to Part I, 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 above.*

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.

3.1.7.6.6 Where the provision of VHF marker beacons is impracticable, a suitably located DME, together with associated monitor system and remote control and indicator equipment shall be an acceptable alternative to part or all of the marker beacon component of the ILS.

Note.— Guidance material relative to the use of DME as an alternative to the marker beacon component of the ILS is contained in Attachment C to Part I, 2.11.

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

3.1.7.6.6.2 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.

3.1.7.6.6.3 The DME in 3.1.7.6.6 above shall conform to the specification in 3.5 below.

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 m² 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 m².

Small twin-engined aircraft: from 15 m².

Medium twin-engined aircraft: from 25 m².

Four-engined aircraft: from 50 to 100 m².

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.— 3.2.3.2.1 above 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 to Part I (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 m² 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 m² echoing area to at least the volume obtained by amending 3.2.4.2.1 above 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 to Part I (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, 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, 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, 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 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 Part II, 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 accuracy of the bearing information conveyed by the horizontally polarized radiation from the VOR at a distance of approximately four wavelengths 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/m².*

Note.— Typical effective radiated powers (ERPs) to achieve specified ranges are contained in 3.1 of Attachment C to Part I.

3.3.5 Modulations of navigational 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 and having a deviation ratio of 16 plus or minus 1 (i.e. 15 to 17):

   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";

   2) for the Doppler VOR, the phase of the 30 Hz component varies with azimuth and is termed the "variable phase";

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 depth of modulation of the radio frequency carrier due to the subcarrier of 9 960 Hz shall be within the limits of 28 per cent and 32 per cent.

3.3.5.3 The depth of modulation of the radio frequency carrier due to the 30 Hz or 9 960 Hz signals, as observed at any angle of elevation up to 5 degrees, shall be within the limits of 28 to 32 per cent.

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 below, the identification provisions of 3.5.3.6.4 below 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 above.

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.— Technical material for the guidance of those who may install or operate the VOR appears in Section 3 of Attachment C to Part I.

3.3.8 Interference immunity performance for VOR receiving systems

3.3.8.1 After 1 January 1998, 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:

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

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

and

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

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 below.

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

3.3.8.2 After 1 January 1998, 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*
88-102	+15 dBm
104	+10 dBm
106	+ 5 dBm
107.9	−10 dBm

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

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

3.3.8.3 After 1 January 1995, all new installations of airborne VOR receiving systems shall meet the provisions of 3.3.8.1 and 3.3.8.2 above.

3.3.8.4 **Recommendation.—** *Airborne VOR receiving systems meeting the immunity performance standards of 3.3.8.1 and 3.3.8.2 above should be placed into operation at the earliest possible date.*

3.4 Specification for non-directional radio beacon (NDB)

3.4.1 Definitions

Note.— In Attachment C to Part I, 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 to Part I, and the relevant ITU provisions are given in Part B, Chapter VIII, Article 35, Section IV 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 co-ordinated 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 Part II, 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 6.5 of Attachment C to Part I.

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 below, 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 6.4 of Attachment C to Part I.

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 which the state of technique and the nature of the service permit.

Note.— Article 5 of the Radio Regulations contains the general provisions with respect to technical characteristics of equipment and emissions. Tolerances with respect to spurious emissions are specified in Appendix 8 to the Radio Regulations and guidance material for the determination of the necessary bandwidth is contained in Appendix 6.

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* Procedures for Air Navigation Services — Aircraft Operations *(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) above.

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 to Part I.

3.5 Specification for UHF distance measuring equipment (DME)

Note 1.— In the following section, provision is made for three types of DME facility: DME/N for application as outlined in Part I, 2.2.2, DME/W only for application as outlined in Part I, 2.2.3, and DME/P as outlined in 3.11.3 below. Except for spectrum, DME/N and DME/W are identical.

Note 2.— The system characteristics in 3.5.3 below are designed to allow for system compatibility.

Note 3.— In the following paragraphs, those denoted by ‡ are applicable to equipment first installed after 1 January 1989.

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 below.)

DME dead time. A period of blanking in the receiver of the transponder to protect it during reply transmission and to prevent responses due 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 (to be distinguished from "W").

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.

DME/W. Distance measuring equipment, primarily serving operational needs of en-route or TMA navigation, where the "W" stands for wide spectrum characteristics (to be distinguished from "N").

Equivalent isotropically radiated power (e.i.r.p.). 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 below.)

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

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.

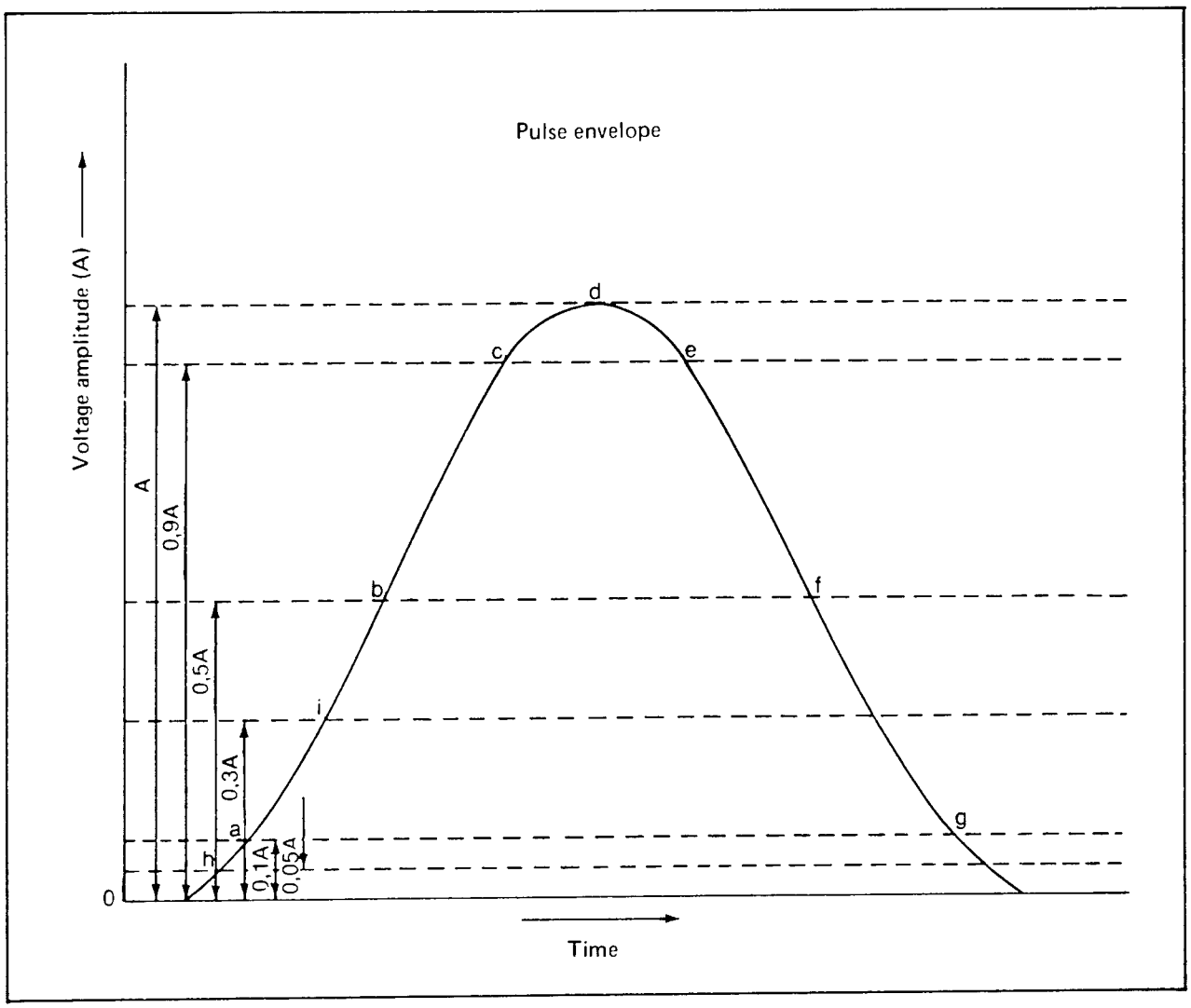


Figure 3-1

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 below.)

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).

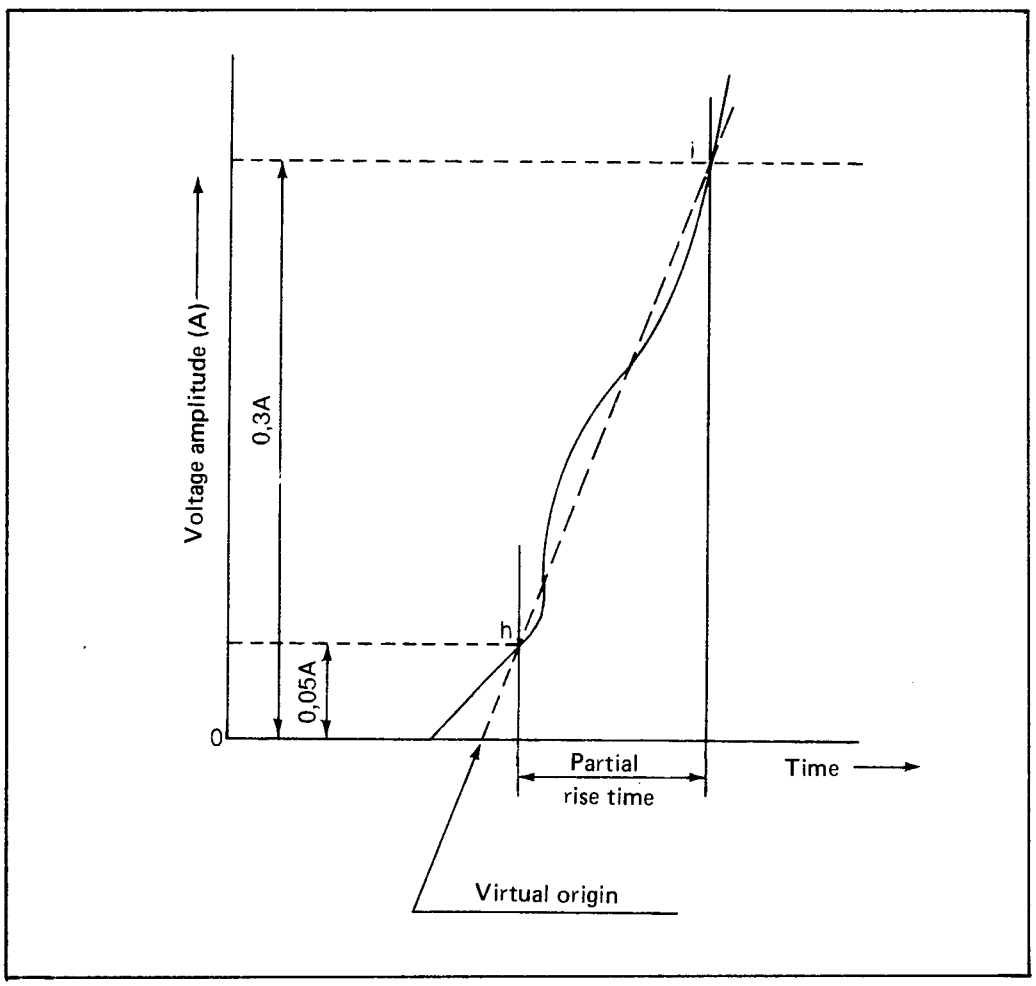


Figure 3-2

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.

3.5.2.5 When a DME function is combined with either an ILS, MLS or VOR for the purpose of constituting a single facility, they shall be considered to be associated in a manner complying with Part I, 2.2.2, only when:

a) operated on a standard frequency pairing in accordance with 3.5.3.3.5 below;

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

c) complying with the identification provisions of 3.5.3.6.4 below.

Note.— A single DME facility may be paired with both an ILS and MLS.

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) *coaxial collocation:* the VOR and DME antennas are located on the same vertical axis; or

b) *offset collocation:*

1) 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 30 m (100 ft) except that, at Doppler VOR facilities, where DME service is provided by a separate facility, the antennas may be separated by more than 30 m (100 ft), but not in excess of 80 m (260 ft);

2) for purposes other than those indicated in 1), 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 to Part I, 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.**— *The DME/P should be sited as close as possible to the MLS azimuth facility.*

Note.— Attachment G to Part I, 5 and Attachment C to Part I, 7.1.6 give guidance on siting of DME with MLS.

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 herein shall be met on a 95 per cent probability basis.

Note.— The total system limits include errors from all causes such as those from airborne equipment, ground equipment, propagation and random pulse interference effects.

3.5.3.1.3.2 *DME/N accuracy.*

Recommendation.— *At distances of from zero to 370 km (200 NM) from the transponder, dependent upon the particular service application, the total system error, excluding reading error, should be not greater than plus or minus 0.9 km (0.5 NM) or plus or minus 3 per cent of distance measured, whichever is the greater.*

Note.— The system is considered to be inherently capable of providing distance information, as indicated to the pilot, accurate to within plus or minus 370 m (0.2 NM), or plus or

minus 0.25 per cent of slant range distance, whichever is greater, at least 95 per cent of the time.

‡3.5.3.1.1.3.3 The total system error shall not exceed plus or minus 370 m (0.2 NM).

Note 1.— This system accuracy is predicated upon the achievement of an airborne interrogator error contribution of not more than plus or minus 310 m (0.17 NM).

Note 2.— In mixed DME/N and DME/P operations it is intended that the achieved accuracy be at least that in 3.5.3.1.3.2 above.

3.5.3.1.1.3.4 *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 to Part I, 7.3.2.

3.5.3.1.1.3.4.1 *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 to Part I, 7.3.6.1.

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

3.5.3.1.1.3.4.3 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 1-MHz 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 Table B at the end of this chapter. 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.

3.5.3.3.3.1 DME operating channels bearing the suffix "Y" in Table A may be chosen, on the basis of regional agreement, when they have become applicable in accordance with the following:

a) for *restricted use* on or after, whichever is the later of:

   1) 1 January 1966; or

   2) a date prescribed by the Council giving a period of two years or more following approval of the regional agreement concerned;

b) for *general use* on or after, whichever is the later of:

   1) 1 January 1970; or

   2) a date prescribed by the Council giving a period of two years or more following approval of the regional agreement concerned.

Note.— "Restricted use" is intended to refer to the limited use of the channels by only suitably equipped aircraft, without imposing any general requirement for the carriage of DME airborne equipment capable of operating on these channels.

3.5.3.3.4 *Area channel assignment*

3.5.3.3.4.1 In a particular area, the number of DME operating channels to be used shall be decided regionally.

Note.— Standards and Recommended Practices on the utilization of the DME frequency band 960-1 215 MHz are found in Part II, 4.3.

3.5.3.3.4.2 The specific DME operating channels to be assigned in such a particular area shall also be decided regionally, taking into consideration the requirements for co-channel and adjacent channel protection.

3.5.3.3.4.3 **Recommendation.—** *Co-ordination of regional DME channel assignments should be effected through ICAO.*

Note.— The above paragraphs permit the use of DME airborne interrogators having less than the total number of operating channels where so desired.

3.5.3.3.5 *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 MHz to

5 091 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.— In the ILS/MLS transition period, there may be instances when a DME will be paired with both the ILS frequency and an MLS channel (see 4.3.3.1 of Part II).

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.— A pulse repetition frequency (PRF) of 5 pulse pairs per second on the ground should not be exceeded, but may be if the aircraft requires accurate range information.

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 to Part I, 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 below:

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.

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 below. 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 above.

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 above).

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 above and shall be synchronized with the VHF or MLS angle 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 specified in 3.11.4.6.2.1 below.

Note.— When DME is associated with both an ILS and an MLS angle facility, it is intended that the DME will serve as the sole synchronization source for all facilities.

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.

3.5.3.6.6 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 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 The transition from IA mode to FA mode track operation may be initiated within 14.8 km (8 NM) from the transponder. Outside 14.8 km (8 NM), the interrogator shall not interrogate in the FA mode.

Note.— 3.5.3.7.1 above 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 3.5.3.1.3.4 above 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 above).

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.

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 effective radiated power 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 effective radiated power 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. Any lobe of the spectrum shall be of less amplitude than the adjacent lobe nearer the nominal channel frequency.

f) For DME/W, the spectrum of the pulse modulated signal shall be such that during the pulse the effective radiated power contained in a 0.5 MHz band centred on

frequencies 1.8 MHz above and 1.8 MHz below the nominal channel frequency in each case shall not exceed 200 mW, and the effective radiated power contained in a 0.5 MHz band centred on frequencies 3 MHz above and 3 MHz below the nominal channel frequency in each case shall not exceed 2 mW. Any lobe of the spectrum shall be of less amplitude than the adjacent lobe nearer the nominal channel frequency.

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) and f) above 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 Table B.

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 effective radiated power should not be less than that required to ensure a peak pulse power density of approximately minus 83 dBW/m² 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/m² under all operational weather conditions at any point within coverage specified in 3.5.3.1.2 above.

Note.— Although the Standard in 3.5.4.1.5.2 above implies an improved interrogator receiver sensitivity, it is intended that the power density specified in 3.5.4.1.5.1 above 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/m² at any point within the coverage specified in 3.5.3.1.2 above at ranges greater than 13 km (7 NM) from the transponder antenna;

b) minus 75 dBW/m² at any point within the coverage specified in 3.5.3.1.2 above at ranges less than 13 km (7 NM) from the transponder antenna;

c) minus 70 dBW/m² at the MLS approach reference datum;

d) minus 79 dBW/m² 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 ERP may be found in Sections 7.2.1 and 7.3.8 of Attachment C to Part I.

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 to Part I, 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.

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 above 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 above 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 above).

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/m² for DME/N;

b) minus 86 dBW/m² for DME/P IA mode;

c) minus 75 dBW/m² for DME/P FA mode.

3.5.4.2.3.2 The minimum power densities specified in 3.5.4.2.3.1 above 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 above up to a maximum of minus 22 dBW/m².

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 above up to a maximum of minus 22 dBW/m².

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 *Sensitivity reduction*

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.* The receiver sensitivity reduction specified in 3.5.4.2.4.1 above shall be applied to the IA mode but not to 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 above 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 above when the input signals are those specified in 3.5.5.1.3 below.

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 above when the input signals are those specified in 3.5.5.1.3 below. 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 above when the input signals are those specified in 3.5.5.1.3 below. 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 minus 22 dBW/m² 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 below.

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 above.

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 connexion, 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 below.

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 75 dB above receiver sensitivity 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 75 dB above receiver sensitivity 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*	*Interr.*	*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 **Recommendation [DME/N].**— *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 should be 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 to Part I and 5 of Attachment G to Part I.

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 over-all system error.

‡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 over-all 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 over-all 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 over-all 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 over-all 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 above and at the minimum sensitivity level specified in 3.5.4.2.3.1 and 3.5.4.2.3.5 above.

Note.— When considering the transponder reply efficiency value, account should be taken of the receiver dead time and any increased dead time allowed for echo suppression purposes.

3.5.4.6.2 *Transponder receiver dead time.* The transponder receiver shall be rendered inoperative for a period normally not to exceed 60 microseconds after an acceptable 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 below 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 above 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 above 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 above 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 above 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 above 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 above 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 effective radiated power to less than that necessary to satisfy the requirements specified in 3.5.4.1.5.3 above 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 above for a period of more than five seconds (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 above by 1.0 microsecond or more for a period of more than one second.

3.5.4.7.3.2 The period during which erroneous guidance information is radiated shall not exceed the periods specified in 3.5.4.7.3.1 above. 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.

3.5.4.7.3.3 The transponder shall not be triggered for monitoring purposes more than 120 times per second.

3.5.4.7.3.4 *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 above).

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.

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.

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

Note 2.— While 3.5.5.1.3 e) above calls for a practically attainable spectrum, it is desirable to strive for the following spectrum control characteristics: the spectrum of the pulse modulated signal should be 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 should, in each case, be 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 should, in each case, be 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 should be 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 above.

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 above.

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 3.5.3.1.3.4 above, 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 to Part I, 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 above should be 80 dB below the required peak pulse power received.*

Note.— Reference 3.5.5.1.6 and 3.5.5.1.7 above — 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 effective radiated power (ERP) shall not be less than that required to ensure the power densities in 3.5.4.2.3.1 above 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 above.

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 above).

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 below for the signal power density specified in 3.5.4.1.5.2 above.

Note.— Although the Standard in ‡3.5.5.3.2.1 above 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 above 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 below for the signal power densities specified in 3.5.4.1.5.3 above.

‡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 above and a maximum of minus 18 dBW/m².

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 above and a maximum of minus 18 dBW/m².

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 above, when the input signals are those specified in 3.5.4.1.3 above.

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 above, when the input signals are those specified in 3.5.4.1.3 above. 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 above when the input signals are those specified in 3.5.5.1.3 above. 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 which 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 above.

‡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) to the over-all 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 over-all system PFE and not more than plus or minus 15 m (plus or minus 50 ft) to the over-all system CMN.

3.5.5.4.3 *DME/P — FA mode*

3.5.5.4.3.1 *Accuracy standard 1.* The interrogator shall not contribute more than plus or minus 15 m (plus or minus

50 ft) to the over-all system PFE and not more than plus or minus 10 m (plus or minus 33 ft) to the over-all system CMN.

3.5.5.4.3.2 *Accuracy standard 2.* The interrogator shall not contribute more than plus or minus 7 m (plus or minus 23 ft) to the over-all system PFE and not more than plus or minus 7 m (plus or minus 23 ft) to the over-all system CMN.

Note.— Guidance material on filters to assist in achieving this accuracy is given in Attachment C to Part I, 7.3.4.

3.5.5.4.4 *DME/P.* The interrogator shall achieve the accuracy specified in 3.5.3.1.3.4 above with a system efficiency of 50 per cent or more.

Note.— Guidance material on system efficiency is given in Attachment C to Part I, 7.1.1.

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

3.6.1 Equipment

3.6.1.1 *Frequencies.* The emissions of an en-route VHF marker beacon shall have a radio frequency of 75 MHz plus or minus 0.02 per cent. As from 1 January 1985 all new installed en-route VHF marker beacons shall have a frequency tolerance of plus or minus 0.005 per cent. After 1 January 1990 this provision applies for all en-route VHF marker beacons.

3.6.1.2 *Characteristics of emissions*

3.6.1.2.1 Radio marker beacons shall radiate an uninterrupted carrier modulated to a depth of not less than 95 per cent nor more than 100 per cent. The total harmonic content of the modulation shall not exceed 15 per cent.

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

3.6.1.2.3 The radiation shall be horizontally polarized.

3.6.1.2.4 *Identification.* If a coded identification is required at a radio marker beacon, the modulating tone shall be keyed so as to transmit dots or dashes or both in an appropriate sequence. The mode of keying shall be such as to provide a dot-and-dash duration together with spacing intervals corresponding to transmission at a rate equivalent to approximately 6 to 10 words per minute. The carrier shall not be interrupted during identification.

3.6.1.2.5 *Coverage and radiation pattern*

Note.— The coverage and radiation pattern of marker beacons will ordinarily be established by Contracting States on the basis of operational requirements, taking into account recommendations of regional meetings.

The most desirable radiation pattern would be one that:

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

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

In practice, the production of such patterns is impracticable and a compromise radiation pattern is necessary. In Attachment C to Part I, antenna systems currently in use and which have proved generally satisfactory are described for guidance. Such designs and any new designs providing a closer approximation to the most desirable radiation pattern outlined above will normally meet operational requirements.

3.6.1.2.6 *Determination of coverage.* The limits of coverage of marker beacons shall be determined on the basis of the field strength specified in 3.1.7.3.2 above.

3.6.1.2.7 *Radiation pattern.*

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

Note.— Difficulty in siting certain marker beacons may make it necessary to accept a polar axis that is not vertical.

3.6.1.3 *Monitoring.*

Recommendation.— *For each marker beacon, suitable monitoring equipment should be provided which will show at an appropriate location:*

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

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

c) a failure of keying.

Note.— Technical material for the guidance of designers and for those who may install or operate marker beacons appears in Attachment C to Part I.

3.7 Consol system characteristics

Introductory Note.— The Consol ground station radiates dot-and-dash signals, and a position line can be determined by making a count of the dot-and-dash characters heard during the navigational keying cycle transmission period. By reference to the appropriate Consol charts or tables, the observer can determine a position line. Since there are five alternative position lines in each coverage sector of 120 degrees, the observer, if in doubt as to which of these is correct, can

generally resolve the ambiguity by taking a bearing on the ground station. The observer can establish his position by reference to two independent Consol ground stations.

3.7.1 Radio frequencies

3.7.1.1 **Recommendation.**— *The radio frequencies assigned to Consol should be selected from those available in that portion of the spectrum between 200 kHz and 415 kHz.*

3.7.2 Identification

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

3.7.3 Navigational keying

Each Consol shall be keyed type A1A. The keying shall provide interlocked dots and dashes of ⅛ second and ⅜ second duration respectively. The navigational keying cycle shall be of approximately 30-second duration and shall be preceded and followed by a silent interval.

Note.— Close adherence to the 30-second navigational keying cycle will facilitate the design of automatic counters.

3.7.3.1 **Recommendation.**— *The duration of the silent interval should be of the order of 2 to 3 seconds.*

3.8 Secondary surveillance radar (SSR) system characteristics

Note 1.— In this section, the four SSR modes are designated by letters A, B, C and D. Suffixed letters, e.g. A_2, B_4, are used to designate the individual pulses used in the air-to-ground pulse trains. This common use of letters is not to be construed as implying any particular association of modes and codes.

Note 2.— Provisions for the recording and retention of radar data are contained in Annex 11, Chapter 6.

3.8.1 Interrogation and control (interrogation side-lobe suppression) radio frequencies (ground-to-air)

3.8.1.1 Centre frequency of the interrogation and control transmissions shall be 1 030 MHz.

3.8.1.2 The frequency tolerance shall be plus or minus 0.2 MHz.

3.8.1.3 Centre frequencies of the control transmission and of each of the interrogation pulse transmissions shall not differ from each other by more than 0.2 MHz.

3.8.2 Reply radio frequency (air-to-ground)

3.8.2.1 Centre frequency of the reply transmission shall be 1 090 MHz.

3.8.2.2 The frequency tolerance shall be plus or minus 3 MHz.

3.8.3 Polarization

3.8.3.1 Polarization of the interrogation, control and reply transmissions shall be predominantly vertical.

3.8.4 Interrogation modes (signals-in-space)

3.8.4.1 The interrogation shall consist of two transmitted pulses designated P_1 and P_3. A control pulse P_2 shall be transmitted following the first interrogation pulse P_1.

3.8.4.2 The four interrogation modes shall be as defined in 3.8.4.3 below.

3.8.4.3 The interval, between P_1 and P_3, shall determine the mode of interrogation and shall be as follows:

Mode A	8 ± 0.2 microseconds
Mode B	17 ± 0.2 microseconds
Mode C	21 ± 0.2 microseconds
Mode D	25 ± 0.2 microseconds

3.8.4.4 The interval between P_1 and P_2 shall be 2.0 plus or minus 0.15 microseconds.

3.8.4.5 The duration of pulses P_1, P_2 and P_3 shall be 0.8 plus or minus 0.1 microsecond.

3.8.4.6 The rise time of pulses P_1, P_2 and P_3 shall be between 0.05 and 0.1 microsecond.

Note.— The intent of the lower limit of rise time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise time.

3.8.4.7 The decay time of pulses P_1, P_2 and P_3 shall be between 0.05 and 0.2 microsecond.

Note.— The intent of the lower limit of decay time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated decay time.

3.8.5 Interrogator and control transmission characteristics (interrogation side-lobe suppression — signals-in-space)

3.8.5.1 The radiated amplitude of P_2 at the antenna of the transponder shall be:

a) equal to or greater than the radiated amplitude of P_1 from the greatest side-lobe transmission of the antenna radiating P_1; and

b) at a level lower than 9 dB below the radiated amplitude of P_1, within the desired arc of interrogation.

3.8.5.2 Within the desired beamwidth of the directional interrogation (main lobe), the radiated amplitude of P_3 shall be within 1 dB of the radiated amplitude of P_1.

3.8.6 Reply transmission characteristics (signals-in-space)

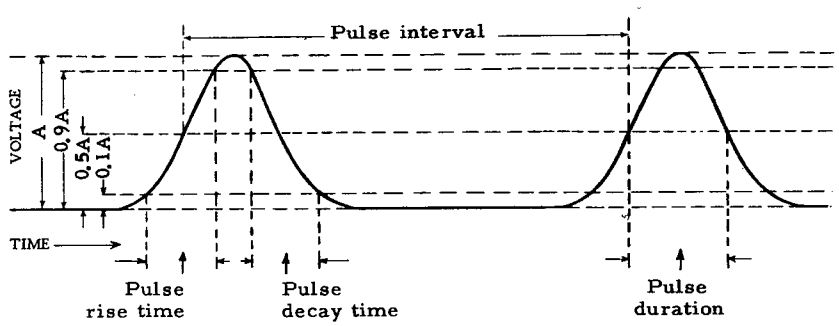
3.8.6.1 *Framing pulses.* The reply function shall employ a signal comprising two framing pulses spaced 20.3 microseconds as the most elementary code.

3.8.6.2 *Information pulses.* Information pulses shall be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses shall be as follows:

Pulses	*Position (microseconds)*
C_1	1.45
A_1	2.90
C_2	4.35
A_2	5.80
C_4	7.25
A_4	8.70
X	10.15
B_1	11.60
D_1	13.05
B_2	14.50
D_2	15.95
B_4	17.40
D_4	18.85

Note.— The Standard relating to the use of these pulses is given in Part I, 2.5.4.1. However, the position of the "X" pulse is specified only as a technical standard to safeguard possible future use. Further guidance on this matter is given in 4.8.5 of Attachment B to Part I.

3.8.6.3 *Special position identification pulse (SPI).* In addition to the information pulses provided, a special position



DEFINITIONS

Pulse amplitude A. The peak voltage amplitude of the pulse envelope.

Pulse duration. The time interval between 0.5A points on leading and trailing edges of the pulse envelope.

Pulse interval. The time interval between the 0.5A point on the leading edge of the first pulse and the 0.5A point on the leading edge of the second pulse.

Pulse rise time. The rise time as measured between 0.1A and 0.9A on the leading edge of the pulse envelope.

Pulse decay time. The decay time as measured between 0.9A and 0.1A on the trailing edge of the pulse envelope.

Figure 3-3. Secondary surveillance radar pulse shape and spacing definitions

identification pulse, which may be transmitted with any of the other information pulses, shall occur at a pulse interval of 4.35 microseconds following the last framing pulse.

3.8.6.4 *Reply pulse shape.* All reply pulses shall have a pulse duration of 0.45 plus or minus 0.1 microsecond, a pulse rise time between 0.05 and 0.1 microsecond and a pulse decay time between 0.05 and 0.2 microsecond. The pulse amplitude variation of one pulse with respect to any other pulse in a reply train shall not exceed 1 dB.

Note.— The intent of the lower limit of rise and decay times (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is not greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise and decay times.

3.8.6.5 *Reply pulse position tolerances.* The pulse spacing tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse interval tolerance of the special position identification pulse with respect to the last framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse spacing tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) shall not exceed plus or minus 0.15 microsecond.

3.8.6.6 *Code nomenclature.* The code designation shall consist of digits between 0 and 7 inclusive, and shall consist of the sum of the subscripts of the pulse numbers given in 3.8.6.2 above, employed as follows:

Digit	*Pulse Group*
First (*most significant*)	A
Second	B
Third	C
Fourth	D

3.8.7 Technical characteristics of the airborne transponder

3.8.7.1 *Reply.* When selected to reply to a particular interrogation mode, the transponder shall reply (not less than 90 per cent triggering) when all of the following conditions have been met:

a) the received amplitude of P_3 is in excess of a level 1 dB below the received amplitude of P_1 but no greater than 3 dB above the received amplitude of P_1;

b) either no pulse is received in the interval 1.3 microseconds to 2.7 microseconds after P_1, or P_1 exceeds by more than 9 dB any pulse received in this interval;

c) the received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the latter are not recognized by the transponder as P_1, P_2 or P_3.

3.8.7.2 The transponder shall not reply under the following conditions:

a) to interrogations when the interval between pulses P_1 and P_3 differs from that specified in 3.8.4.3 above for the mode selected in the transponder by more than plus or minus 1.0 microsecond;

b) upon receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

3.8.7.3 *Dead time.* After reception of a proper interrogation, the transponder shall not reply to any other interrogation, at least for the duration of the reply pulse train. This dead time shall end no later than 125 microseconds after the transmission of the last reply pulse of the group.

3.8.7.4 *Suppression*

3.8.7.4.1 Upon receipt of an interrogation complying with 3.8.4 above in respect of the mode selected manually or automatically, the transponder shall be suppressed when the received amplitude of P_2 is equal to, or in excess of, the received amplitude of P_1 and spaced 2.0 plus or minus 0.15 microseconds. The detection of P_3 is not required as a prerequisite for initiation of suppression action.

3.8.7.4.2 The transponder suppression shall be for a period of 35 plus or minus 10 microseconds.

3.8.7.4.2.1 The suppression shall be capable of being reinitiated for the full duration within 2 microseconds after the end of any suppression period.

3.8.7.5 *Receiver sensitivity and dynamic range*

3.8.7.5.1 The minimum triggering level of the transponder shall be such that replies are generated to at least 90 per cent of the interrogation signals when:

a) the two pulses P_1 and P_3 constituting an interrogation are of equal amplitude and P_2 is not detected; and

b) the amplitude of these signals received at the antenna of the transponder is nominally 71 dB below 1 mW, with limits between 69 dB and 77 dB below 1 mW.

3.8.7.5.2 The reply and suppression characteristics shall apply over a received amplitude of P_1 between minimum triggering level and 50 dB above that level.

3.8.7.5.3 The variation of the minimum triggering level between modes shall not exceed 1 dB for nominal pulse spacings and pulse widths.

3.8.7.6 *Pulse duration discrimination.* Signals of received amplitude between minimum triggering level and 6 dB above this level, and of a duration less than 0.3 microsecond, shall not cause the transponder to initiate reply or suppression action. With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of

a duration more than 1.5 microseconds shall not cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level (MTL) to 50 dB above that level.

3.8.7.7 *Echo suppression and recovery.* The transponder shall contain an echo suppression facility designed to permit normal operation in the presence of echoes of signals-in-space. The provision of this facility shall be compatible with the requirements for suppression of side lobes given in 3.8.7.4.1 above.

3.8.7.7.1 *Desensitization.* Upon receipt of any pulse more than 0.7 microsecond in duration, the receiver shall be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse but shall at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse.

Note.— Single pulses of duration less than 0.7 microsecond are not required to cause the specified desensitization nor to cause desensitization of duration greater than permitted by 3.8.7.7.1 above and 3.8.7.7.2 below.

3.8.7.7.2 *Recovery.* Following desensitization, the receiver shall recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. Recovery shall be nominally linear at an average rate not exceeding 3.5 dB per microsecond.

3.8.7.8 *Random triggering rate.* Installation in the aircraft shall be made in such manner that, with all possible interfering equipments installed in the same aircraft operating in their normal manner on operational channels of maximum interference, but with the absence of *bona fide* interrogations, the random triggering rate (squitter) of the transponder shall not exceed 30 replies per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less.

3.8.7.9 *Reply rate*

3.8.7.9.1 The transponder shall be capable of at least 1 200 replies per second for a 15-pulse coded reply, except that, for transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, transponders capable of at least 1 000 replies per second for a 15-pulse coded reply shall be permitted.

3.8.7.9.2 *Reply rate limit control.* To protect the system from the effects of transponder over-interrogation by preventing response to weaker signals when a predetermined reply rate has been reached, a sensitivity reduction type reply limit control shall be incorporated in the equipment. The range of this control shall permit adjustment, as a minimum, to any value between 500 and 2 000 replies per second, or to the maximum reply rate capability if less than 2 000 replies per second, without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB shall not take effect until 90 per cent of the selected value is exceeded. Sensitivity reduction shall be at least 30 dB for rates in excess of 150 per cent of the selected value.

3.8.7.9.3 **Recommendation.**— *The reply rate limit should be set at 1 200 replies per second, or the maximum value below 1 200 replies per second of which the transponder is capable.*

3.8.7.10 *Reply delay and jitter.* The time delay between the arrival, at the transponder receiver, of the leading edge of P_3 and the transmission of the leading edge of the first pulse of the reply shall be 3 plus or minus 0.5 microseconds. The total jitter of the reply pulse code group, with respect to P_3, shall not exceed 0.1 microsecond for receiver input levels between 3 dB and 50 dB above minimum triggering level. Delay variations between modes on which the transponder is capable of replying shall not exceed 0.2 microsecond.

3.8.7.11 *Transponder power output and duty cycle*

3.8.7.11.1 The peak pulse power available at the antenna end of the transmission line of the transponder shall be at least 21 dB and not more than 27 dB above 1 W, except that for transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, a peak pulse power available at the antenna end of the transmission line of the transponder of at least 18.5 dB and not more than 27 dB above 1 W shall be permitted.

3.8.7.11.2 **Recommendation.**— *The peak pulse power specified in 3.8.7.11.1 above should be maintained over a range of replies from code 0000 at a rate of 400 replies per second to a maximum pulse content at a rate of 1 200 replies per second or a maximum value below 1 200 replies per second of which the transponder is capable.*

3.8.7.12 *Reply codes*

3.8.7.12.1 *Identification.* The 4 096 codes available in the Standard at 3.8.6.2 above shall be manually selectable for reply to interrogations on Mode A.

3.8.7.12.2 *Pressure-altitude transmission.* Independently of the other modes and codes manually selected, the transponder shall automatically reply to Mode C interrogation.

3.8.7.12.2.1 The reply to Mode C interrogation shall consist of the two framing pulses specified in 3.8.6.1 above, together with information pulses specified in 3.8.6.2 above.

3.8.7.12.2.2 At as early a date as practicable transponders shall be provided with means to remove the information pulses but to retain the framing pulses when the provision of 3.8.7.12.2.5 below is not complied with in reply to Mode C interrogation.

3.8.7.12.2.3 The information pulses shall be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 1 013.25 hPa.

3.8.7.12.2.4 Pressure-altitude shall be reported in 100-foot increments by selection of pulses as shown in Table B at the end of this chapter.

3.8.7.12.2.5 The digitizer code selected shall correspond to within plus or minus 37.5 m (125 ft), on a 95 per cent probability basis, with the pressure-altitude information (referenced to the standard pressure setting of 1 013.25 hPa), used on board the aircraft to adhere to the assigned flight profile.

Note.— Guidance material relating to pressure-altitude transmission is contained in 4.8.4 of Attachment B to Part I.

3.8.7.13 Transmission of the special position identification (SPI) pulse. This additional pulse shall be transmitted for a period of between 15 and 30 seconds and only as a result of manual (pilot) selection.

3.8.7.14 *Antenna*

3.8.7.14.1 The transponder antenna system, when installed on an aircraft, shall have a radiation pattern which is essentially omnidirectional in the horizontal plane.

3.8.7.14.2 **Recommendation.**— *The vertical beamwidth (half power points) should be at least 30 degrees above and below the horizontal plane.*

3.8.8 Technical characteristics of the ground interrogator

3.8.8.1 *Interrogation repetition frequency.* The maximum interrogation repetition frequency shall be 450 interrogations per second.

3.8.8.1.1 **Recommendation.**— *To minimize unnecessary transponder triggering and the resulting high density of mutual interference, all interrogators should use the lowest practicable interrogator repetition frequency that is consistent with the display characteristics, interrogator antenna beam width and antenna rotation speed employed.*

3.8.8.2 *Radiated power.* The effective radiated peak power of the interrogation pulses (P_1 and P_3) shall not exceed 52.5 dB above 1 W. The amplitude of P_3 shall be within 1 dB of the amplitude of P_1.

3.8.8.2.1 **Recommendation.**— *In order to minimize system interference the effective radiated peak power of interrogators should be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.*

3.8.8.3 **Recommendation.**— *When Mode C information is to be used from aircraft flying below transition levels, all relevant guidance material should be taken into account.*

Note.— Attention is drawn to the guidance material on this subject given in Section 6 of Attachment B to Part I. Use of Mode C below transition levels is in accordance with the philosophy that Mode C can usefully be employed in all environments.

3.8.9 Interrogator radiated field pattern

Recommendation.— *The beam width of the directional interrogator antenna radiating P_3 should not be wider than is operationally required. The side- and back-lobe radiation of the directional antenna should be at least 24 dB below the peak of the main-lobe radiation.*

3.8.10 Interrogator monitor

3.8.10.1 The range and azimuth accuracy of the ground interrogator shall be monitored continuously.

Note.— Interrogators that are associated with and operated in conjunction with primary radar may use the primary radar as the monitoring device; alternatively, an electronic range and azimuth accuracy monitor would be required.

3.8.10.2 **Recommendation.**— *In addition to range and azimuth monitoring, provision should be made to monitor continuously the other critical parameters of the ground interrogator for any degradation of performance exceeding the allowable system tolerances and to provide an indication of any such occurrence.*

Note.— Guidance on those system parameters for which continuous or periodic monitoring provisions are of particular importance is to be found in 4.7 of Attachment B to Part I.

3.8.11 Spurious emissions and spurious responses

3.8.11.1 *Spurious radiation.*

Recommendation.— *CW radiation should not exceed 76 dB below 1 W for the interrogator and 70 dB below 1 W for the transponder.*

3.8.11.2 *Spurious responses.*

Recommendation.— *The response of both airborne and ground equipment to signals not within the receiver pass band should be at least 60 dB below normal sensitivity.*

3.9 System characteristics of airborne ADF receiving systems

3.9.1 Accuracy of bearing indication

3.9.1.1 The bearing given by the ADF system shall not be in error by more than plus or minus 5 degrees with a radio signal from any direction having a field strength of 70 microvolts per metre or more radiated from an LF/MF NDB or locator operating within the tolerances permitted by this Annex and in the presence also of an unwanted signal from a direction 90 degrees from the wanted signal and:

1) on the same frequency and 15 dB weaker; or

2) plus or minus 2 kHz away and 4 dB weaker; or

3) plus or minus 6 kHz or more away and 55 dB stronger.

Note.— The above bearing error is exclusive of aircraft magnetic compass error.

3.10 Loran-A system characteristics

3.10.1 General

3.10.1.1 The Loran-A system shall provide accurately timed pulses of radio frequency energy from pairs of associated stations such that measurements in an aircraft of the difference of time of arrival of the pulses from each pair determine the hyperbolic line of position of the aircraft. Two such intersecting lines determine the position of the aircraft.

3.10.1.2 The system shall be comprised of a master station transmitting pulses received directly by the aircraft, and effectively triggering other slave stations of the system. When triggered by the master station, slave stations transmit synchronized pulses for reception by the same aircraft.

3.10.2 System characteristics

3.10.2.1 The Loran-A pulse shall have a nominal rise time of 21 microseconds plus or minus 1 microsecond and a nominal pulse width of 40 microseconds plus or minus 1 microsecond.

3.10.2.2 *Pulse spectrum.* The peaks of the sideband energy on either side of the carrier frequency shall be down from the carrier frequency in amplitude, as follows:

Frequency	*Attenuation*
± 25 kHz	−20 dB or lower
± 50 kHz	−40 dB or lower
±120 kHz	−70 dB or lower

3.10.2.3 The Loran-A pulse repetition period shall be assigned a value from the table of 3.10.3.3 below between 29 300 and 50 000 microseconds for identification. The assigned period shall be maintained within 0.01 microsecond.

3.10.2.4 A pair shall be comprised of a master station transmitting accurately timed pulses and a slave station transmitting pulses accurately delayed from the master pulse by the time distance between the stations plus one-half the pulse repetition period, plus an additional coding delay, usually 1 000 microseconds with an over-all tolerance of plus or minus 2 microseconds.

Note 1.— Accuracy of signal-in-space for a 2-microsecond timing tolerance. *Within 80 per cent of the Loran-A coverage areas involved, ground wave line-of-position is accurate to approximately 2.8 km (1.5 NM), and sky wave line-of-position is accurate to within 13 km (7 NM).*

Note 2.— The limits of accuracy in relation to the geometric configuration of ground stations are defined by a circle drawn through each station of the pair, and having its centre located on the perpendicular bisector of the base line with a radius equal to six times the base line length.

Note 3.— Coverage. *At sea level, ground wave coverage may be expected to at least 1 112 km (600 NM) over water, and sky wave coverage to over 1 853 km (1 000 NM) over either land or water.*

3.10.3 Identification

3.10.3.1 A Loran-A pair shall be identified by the channel number, and the basic rate and specific rate of the pulse repetition period.

3.10.3.2 *Loran-A channel frequencies.*

Channel No.	*Frequency*
1	1 950 kHz
2	1 850 kHz
3	1 900 kHz

3.10.3.3 *Loran-A specific pulse repetition periods:*

	Basic rate (period in microseconds)		
Specific rate	*S*	*L*	*H*
0	50 000	40 000	30 000
1	49 900	39 900	29 900
2	49 800	39 800	29 800
3	49 700	39 700	29 700
4	49 600	39 600	29 600
5	49 500	39 500	29 500
6	49 400	39 400	29 400
7	49 300	39 300	29 300

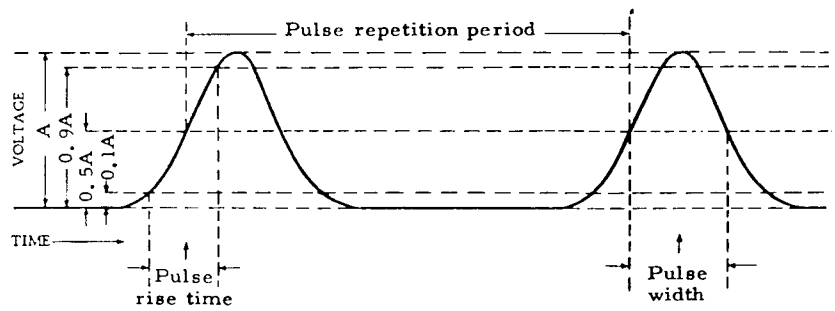
Example: Loran pair 2L4 designates Channel 2, 1 850 kHz basic rate L and specific rate 39 600 microseconds.

3.10.4 Siting

3.10.4.1 **Recommendation.—** *The distance between the master and its slave station should be as great as practicable, having regard for the necessity of continuous reception of the master pulses by the slave station for synchronization and the reception of pulses from both stations by aircraft in the required service area.*

3.10.5 Monitoring

3.10.5.1 **Recommendation.—** *Monitoring of operation should normally be conducted at the master station by electronic observation and recording of the difference of time*



DEFINITIONS

Pulse amplitude A. The peak voltage of the pulse envelope.

Pulse width. The time interval (microseconds) between 0.5A points on leading and trailing edges of the pulse envelope.

Pulse repetition period (PRP). The time interval (microseconds) between the 0.5A point on the leading edge of the first pulse and the 0.5A point on the leading edge of the following pulse from the same station.

Pulse rise time. The time interval (microseconds) between 0.1A point and 0.9A point on the leading edge of the pulse envelope.

Loran pair. A synchronized master station and slave station operating on the same radio frequency with the same pulse repetition period and serving a particular geographic area.

Loran chain. A group of two or more co-ordinated Loran pairs covering the same general geographic area.

Figure 3-4. Loran-A pulse shape and spacing definitions

of arrival between master and slave pulses and visual observation of the characteristics of the pulses transmitted from the master and slave stations.

3.10.5.2 **Recommendation.**— *When the difference of time of arrival of the monitored signals varies from normal by more than 2 microseconds, the user should be notified of the unusable condition by a shifting of the relative position of the master or slave pulses, at 1-second intervals. This "blink" signal may be produced by regularly shifting the time position of the master or slave pulses, or both, back and forth approximately 1 000 microseconds.*

3.11 Microwave landing system (MLS) characteristics

3.11.1 Definitions

Auxiliary data. Data, transmitted in addition to basic data, that provide:

a) ground equipment siting information for use in refining airborne position calculations;

b) meteorological information;

c) runway status; and

d) other supplementary information.

Basic data. Data transmitted by the ground equipment that are associated directly with the operation of the landing guidance system, and advisory data on the MLS ground equipment performance level.

Beam centre. The midpoint between the two minus 3-dB points on the leading and trailing edges of the scanning beam main lobe.

Beamwidth. The width of the scanning beam main lobe measured at the minus 3-dB points and defined in angular units on the boresight, in the horizontal plane for the azimuth function and in the vertical plane for the elevation function.

Clearance guidance sector. The volume of airspace, inside the coverage sector, within which the azimuth guidance information provided is not proportional to the angular displacement of the aircraft, but is a constant left or right indication of which side the aircraft is with respect to the proportional guidance sector.

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 3.5 above.)

Co-ordinate system — conical. A function is said to use conical co-ordinates when the decoded guidance angle varies as the minimum angle between the surface of a cone containing the receiver antenna, and a plane perpendicular to the axis of the cone and passing through its apex. The apex of the cone is at the antenna phase centre. For approach azimuth or back azimuth functions, the plane is the vertical plane containing the runway centre line. For elevation functions, the plane is horizontal.

Co-ordinate system — planar. A function is said to use planar co-ordinates when the decoded guidance angle varies as the angle between the plane containing the receiver antenna and a reference plane. For azimuth functions, the reference plane is the vertical plane containing the runway centre line and the plane containing the receiver antenna is a vertical plane passing through the antenna phase centre.

Coverage sector. A volume of airspace within which service is provided by a particular function and in which the signal power density is equal to or greater than the specified minimum.

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

Function. A particular service provided by the MLS, e.g. approach azimuth guidance, back azimuth guidance or basic data, etc.

Mean course error. The mean value of the azimuth error along the runway extended centre line.

Mean glide path error. The mean value of the elevation error along the glide path of an elevation function.

Minimum glide path. The lowest angle of descent along the zero degree azimuth that is consistent with published approach procedures and obstacle clearance criteria.

MLS approach reference datum. A point on the minimum glide path at a specified height above the threshold. (See 3.5 above.)

MLS back azimuth reference datum. A point at a specified height above the runway centre line at the runway midpoint.

MLS datum point. The point on the runway centre line closest to the phase centre of the approach elevation antenna. (See 3.5 above.)

Out-of-coverage indication signal. A signal radiated into areas outside the intended coverage sector where required to specifically prevent invalid removal of an airborne warning indication in the presence of misleading guidance information.

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 3.5 above.)

Path following noise (PFN). That portion of the guidance signal error which could cause aircraft displacement from the mean course line or mean glide path as appropriate.

Proportional guidance sector. The volume of airspace within which the angular guidance information provided by a function is directly proportional to the angular displacement of the airborne antenna with respect to the zero angle reference.

3.11.2 General

3.11.2.1 MLS is a precision approach and landing guidance system which provides position information and various ground-to-air data. The position information is provided in a wide coverage sector and is determined by an azimuth angle measurement, an elevation angle measurement and a range (distance) measurement.

Note.— Unless specifically indicated as the MLS airborne equipment, the text in 3.11 above 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 transmission of basic data words, associated monitor, remote control and indicator equipment;

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

3.11.3.2 **Recommendation.—** *In order to provide precise ranging information throughout the azimuth coverage sector, the DME should be DME/P. Where for operational reasons precision range is not required, it shall be permissible to install DME, conforming to the Standards of 3.5 above in place of DME/P.*

Note 1.— It is intended that detailed DME/P specifications including channelling be incorporated, in the future, into 3.5 above, "Specification for UHF distance measuring equipment (DME)".

Note 2.— DME is the MLS ranging element and is expected to be installed as soon as possible. However, during the stage of transition from ILS to MLS, marker beacons installed for ILS may be used temporarily but in no case beyond the ILS protection date.

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 transmission of auxiliary data words, associated monitor, remote control and indicator equipment;

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

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

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 shown in Table A.

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 taken in accordance with the provisions of 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.* 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 minus 100.5 dBW/m² for angle guidance and minus 95.5 dBW/m² for data, as measured in a 150 kHz bandwidth centred 840 kHz or more from the nominal frequency.

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.

3.11.4.3 *Time-division-multiplex (TDM) organization*

3.11.4.3.1 Both angle information and data shall be transmitted by TDM on a single radio frequency channel.

3.11.4.3.2 *Synchronization.* The transmissions from the various angle and data ground equipments serving a particular runway shall be time synchronized to assure interference-free operations on the common radio frequency channel of operation.

3.11.4.3.3 *Function rates.* Each function transmitted shall be repeated at the rates shown in the following table:

Function	*Average rate (Hz) measured over any 10-second period*
Approach azimuth guidance	13 ± 0.5
High rate approach azimuth guidance	39 ± 1.5
Back azimuth guidance	6.5 ± 0.25
Approach elevation guidance	39 ± 1.5
Flare elevation guidance	39 ± 1.5
Basic data	see Part I, Appendix A, Table A-7

3.11.4.3.3.1 **Recommendation.**— *When the proportional guidance sector is not greater than plus or minus 40 degrees and a need for flare elevation or other growth functions at that facility is not anticipated, the high rate approach azimuth function should be used.*

Note.— Application information is contained in Attachment G to Part I, 2.3.3.

3.11.4.3.4 *Function timing.* Timing standards for each angle and data function shall be as specified in Appendix A to Part I, Tables A-1 through A-6 and A-8. The ground equipment internal timing accuracy of each listed event including jitter shall be the specified nominal value plus or minus 2 microseconds. The timing jitter shall be less than 1 microsecond route mean square (RMS).

Note 1.— The timing of each listed event indicates the beginning of the event time slot and the end of the previous event time slot. The characteristics and timing of the actual transmissions are as specified in the applicable paragraphs.

Note 2.— Information on the measurement of the timing accuracy is contained in Attachment G to Part I, 2.2.2.

3.11.4.3.5 *Function sequence.* The time interval between repetitive transmissions of any one function shall be varied in a manner which provides protection from synchronous interference.

Note 1.— Each function transmission is an independent entity which can occur in any position in the TDM sequence (with the exception that back azimuth must be preceded by basic data word No. 2).

Note 2.— Some sequences which have demonstrated protection from synchronous interference are illustrated in Attachment G to Part I, 2.1.4.

3.11.4.4 *Preamble*

3.11.4.4.1 A preamble signal shall be transmitted throughout the applicable coverage sector to identify the particular function to follow. The preamble shall consist of a radio frequency carrier acquisition period, a receiver reference time code, and a function identification code. The timing of the preamble transmissions shall be as specified in Appendix A to Part I, Table A-1.

3.11.4.4.2 *Carrier acquisition.* The preamble transmission shall begin with a period of unmodulated radio frequency carrier as specified in Appendix A to Part I, Table A-1.

3.11.4.4.3 *Modulation and coding*

3.11.4.4.3.1 *Differential phase shift keying (DPSK).* The preamble codes and the basic and auxiliary data signals specified in 3.11.4.8 below shall be transmitted by DPSK of the radio frequency carrier. A "zero" shall be represented by a 0 degrees plus or minus 10 degrees phase shift and a "one" shall be represented by a 180 degrees plus or minus 10 degrees phase shift. The modulation rate shall be 15 625 bauds. The internal timing accuracy of the DPSK transition shall be as specified in 3.11.4.3.4 above. The phase transition shall be as fast as possible while remaining consistent with the requirements of 3.11.4.1.4 above.

3.11.4.4.3.2 *Receiver reference time.* All preambles shall contain the receiver reference time code, 11101 (bits I_1 to I_5). The time of the last phase transition in the code shall be the receiver reference time. The receiver reference time code shall be validated by decoding a valid function identification immediately following the receiver reference time code.

3.11.4.4.3.3 *Function identification.* A code for function identification shall follow the receiver reference time code. This code shall consist of the five information bits (I_6 to I_{10}) allowing identification of 31 different functions, plus two parity bits (I_{11} and I_{12}) as shown in the following table:

	Code						
Function	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}
Approach azimuth	0	0	1	1	0	0	1
High rate approach azimuth	0	0	1	0	1	0	0
Approach elevation	1	1	0	0	0	0	1
Flare elevation	0	1	1	0	0	0	1
Back azimuth	1	0	0	1	0	0	1
360° azimuth	0	1	0	0	1	0	1
Basic data 1	0	1	0	1	0	0	0
Basic data 2	0	1	1	1	1	0	0
Basic data 3	1	0	1	0	0	0	0
Basic data 4	1	0	0	0	1	0	0
Basic data 5	1	1	0	1	1	0	0
Basic data 6	0	0	0	1	1	0	1
Basic data 7	1	1	1	0	0	1	0
Basic data 8	1	0	1	0	1	1	1
Auxiliary data	1	1	1	1	0	0	0

Note.— The function identification codes have been chosen so that parity bits I_{11} and I_{12} obey the equations:

$$I_6 + I_7 + I_8 + I_9 + I_{10} + I_{11} = \text{EVEN}$$

$$I_6 + I_8 + I_{10} + I_{12} = \text{EVEN}$$

3.11.4.5 *Angle guidance parameters.* Angle guidance information shall be encoded by the amount of time separation between the centres of the received TO and FRO scanning beam main lobes. The coding shall be interpreted in the airborne equipment as a linear function of time as follows:

$$\theta = (T_0 - t)\ V/2$$

where:

θ = Azimuth or elevation guidance angle in degrees

t = Time separation in microseconds between TO and FRO beam centres

T_0 = Time separation in microseconds between TO and FRO beam centres corresponding to zero degrees

V = Scan velocity scaling constant in degrees per microsecond.

3.11.4.5.1 The values of the angle guidance parameters shall be as shown in the following table:

Function	*Maximum scan angle (degrees)*	*Value of t for maximum scan angle (μs)*	*T_0 (μs)*	*V (degrees/μs)*
Approach azimuth	−62 to +62	13 000	6 800	0.020
High rate approach azimuth	−42 to +42	9 000	4 800	0.020
Back azimuth	−42 to +42	9 000	4 800	−0.020
Approach elevation	−1.5 to +29.5	3 500	3 350	0.020
Flare elevation	−2 to ±10	3 200	2 800	0.010

Note.— Between the end of the TO scan and the beginning of the FRO scan there is a pause time of no radiation of appropriate duration. Additional information is provided in Attachment G to Part I, 2.2.1.

3.11.4.5.2 The tolerances on the ground equipment scanning beam velocity and the time separation between TO and FRO pulses corresponding to zero degrees shall be sufficient to satisfy the accuracy requirements specified in 3.11.4.9 below.

3.11.4.5.3 The TO and FRO scan transmissions shall be symmetrically disposed about the mid-scan point listed in each of Tables A-2 through A-5 of Appendix A to Part I. The mid-scan point and the centre of the time interval between the TO and FRO scan transmissions shall coincide with a tolerance of plus or minus 10 microseconds.

3.11.4.6 *Azimuth guidance functions*

3.11.4.6.1 Each transmission of a guidance angle shall consist of a clockwise TO scan followed by a counter-clockwise FRO scan as viewed from above the antenna. For approach azimuth functions, increasing angle values shall be in the direction of the TO scan. For the back azimuth functions, increasing angle values shall be in the direction of the FRO scan.

Note.— A diagram illustrating the scanning conventions is provided in Attachment G to Part I, 2.3.1.

3.11.4.6.2 *Sector signals.* The transmission format of any azimuth function shall include time slots for ground equipment identification, airborne antenna selection, out-of-coverage indication, and test pulses as specified in Appendix A to Part I, Tables A-2 and A-3. The internal timing accuracy of the sector signals shall conform to the internal timing accuracy of the DPSK transitions specified in 3.11.4.3.4 above.

3.11.4.6.2.1 *Ground equipment identification.* The MLS providing services for a particular runway shall be identified by a four-character alphabetic designator starting with the letter M. This designator shall be encoded in International Morse Code. The code shall be transmitted at approximately equal intervals not less than 6 times per minute. The code shall be transmitted by the approach azimuth and back azimuth ground equipment by the use of a DPSK Morse code bit following the preamble. A "one" shall initiate a Morse code symbol and "zero" shall terminate the symbol. The dot shall be a time duration of 0.13 to 0.16 second and the dash shall be 0.39 to 0.48 second. The time duration between Morse code symbols shall be equal to that of one dot plus or minus 10 per cent. The time duration between characters shall not be less than three dots.

Note.— The ground equipment identification is also provided as a digital word as listed in Appendix A to Part I, Table A-7, and transmitted on the data channel alternately between approach and back azimuth functions.

3.11.4.6.2.2 *Airborne antenna selection signal.* A signal for airborne antenna selection shall be transmitted as a "zero" DPSK signal lasting for a six-bit period following the Morse code bit. The signal shall be available throughout the coverage sector in which approach or back azimuth guidance is provided.

Note.— The signal provides an opportunity for the selection of the most appropriate antenna in a multiple antenna airborne installation.

3.11.4.6.2.3 *Azimuth out-of-coverage indication pulses.* Where out-of-coverage indication pulses are used, they shall be:

1) greater than any guidance signal in the out-of-coverage sector;

2) at least 5 dB less than the fly-left (fly-right) clearance level within the fly-left (fly-right) clearance sector; and

3) at least 5 dB less than the scanning beam level within the proportional coverage region.

The duration of each pulse measured at the half amplitude point shall be 100 (plus or minus 10) microseconds, and the rise and fall times shall be less than 10 microseconds.

3.11.4.6.2.3.1 If desired, it shall be permissible to sequentially transmit two pulses in each out-of-coverage indication time slot. Where the pulse pairs are used, the duration of each pulse shall be 45 (plus or minus 5) microseconds and the rise and fall times shall be less than 10 microseconds.

3.11.4.6.2.4 *Ground radiated test signals.*

Note.— Time has been reserved in the azimuth angle guidance signal formats for the future use of a ground radiated test signal.

3.11.4.6.2.5 *Clearance guidance.* Where the proportional guidance sector provided is less than the minimum coverage specified in 3.11.5.2.2.1.1 a) and 3.11.5.2.2.2 a) below, clearance guidance shall be provided to supplement the coverage sector by the transmission of fly-left/fly-right clearance pulses in the formats for the approach azimuth, high rate approach azimuth and back azimuth functions. Alternatively, it shall be permissible to provide clearance guidance by permitting the scanning beam to scan beyond the designated proportional guidance sector to provide fly-left or fly-right clearance information as appropriate when the decoded angle exceeds the designated limits of proportional guidance coverage.

3.11.4.6.2.5.1 Clearance guidance information shall be provided by transmitting pairs of pulses within the angle scan time slots. One pair shall consist of one pulse adjacent to the start time of the scanning beam TO scan and one pulse adjacent to the stop time of the FRO scan. A second pair shall consist of one pulse adjacent to the stop time of the scanning beam TO scan, and one pulse adjacent to the start time of the FRO scan. The fly-right clearance pulses shall represent positive angles and the fly-left clearance pulses shall represent negative angles. The duration of each clearance pulse shall be 50 microseconds with a tolerance of plus or minus 5 microseconds. The transmitter switching time between the clearance pulses and the scanning beam transmissions shall not exceed 10 microseconds. The rise time at the edge of each clearance pulse not adjacent to the scanning beam shall be less than 10 microseconds.

3.11.4.6.2.5.2 In the fly-right clearance guidance sector, the transmitted fly-right clearance pulses shall exceed the transmitted fly-left clearance pulse by more than 15 dB and shall exceed the side-lobes of the scanning beam signal and any other signal by at least 5 dB. The fly-right clearance pulse shall be at least 5 dB below the scanning beam level at the scanning beam positive angle scan limit. The converse shall apply to the fly-left clearance guidance sector.

3.11.4.6.2.5.3 The power density of the clearance signal shall be as required in 3.11.4.10.1 below.

Note 1.— Attachment G to Part I, 2.3.4 contains guidance information on the following:

a) clearance and scanning beam timing arrangements;

b) pulse envelopes in the transition regions between clearance and scanning beam signals;

c) clearance (fly-right/fly-left) convention changes.

Note 2.— The proportional coverage limits are transmitted in basic data as specified in 3.11.4.8.2 below.

3.11.4.7 *Elevation guidance functions*

3.11.4.7.1 *Scanning conventions.* For the approach elevation and flare elevation functions, increasing elevation guidance angles shall be in the upward direction. Zero elevation angle shall coincide with a horizontal plane through the respective antenna phase centre. Each guidance angle transmission shall consist of a TO scan followed by a FRO scan. The TO scan shall be in the direction of increasing angle values.

3.11.4.7.2 *Sector signal.* Provision for transmission of one out-of-coverage indication pulse shall be made in the format for the approach elevation function. Where an out-of-coverage indication pulse is used, it shall be: (1) greater than any guidance signal in the out-of-coverage indication sector and (2) at least 5 dB less than the guidance signals within the guidance sector. The elevation out-of-coverage indication timing shall be as shown in Appendix A to Part I, Table A-4. The duration of each pulse measured at the half amplitude points shall be 100 plus or minus 10 microseconds, and the rise and fall times shall be less than 10 microseconds.

3.11.4.7.2.1 If desired, it shall be permissible to sequentially transmit two pulses in each obstacle clearance indication time slot. Where pulse pairs are used, the duration of each pulse shall be 45 plus or minus 5 microseconds, and the rise and fall times shall be less than 10 microseconds.

3.11.4.8 *Data functions.* Provision shall be made in the MLS signal format for the transmission of basic data and auxiliary data.

Note.— Ground equipment data transmission requirements are specified in 3.11.5.4 below.

3.11.4.8.1 *Data transmission.* Data shall be transmitted as specified in 3.11.4.4.3.1 above.

3.11.4.8.2 *Basic data structure and timing.* Basic data shall be encoded as 32-bit words consisting of a function preamble (12 bits) specified in 3.11.4.4 above, and data content as specified in Appendix A to Part I, Table A-7. The timing of the basic data words shall be as specified in Appendix A to Part I, Table A-6. The content, maximum interval between transmission of the same word and organization of the words shall be as specified in Appendix A to Part I, Table A-7. Data containing digital information shall be transmitted with the least significant bit first and the smallest binary number shall represent the lower range limit with increments in binary steps to the upper range limit specified in Appendix A to Part I, Table A-7.

3.11.4.8.2.1 *Basic data contents.* The data items specified in Appendix A, Part I, Table A-7 shall be defined as follows:

a) *Approach azimuth to threshold distance* shall represent the distance measured parallel to the runway centre line from the approach azimuth antenna to the runway landing threshold.

b) *Approach azimuth proportional coverage limit* shall represent the limit of the sector in which proportional approach azimuth guidance is transmitted.

*c) *Ground equipment performance level* shall represent the operational status of the equipment in use.

d) *Approach elevation antenna height* shall represent the height of the elevation antenna phase centre relative to the height of the MLS datum point.

e) *Approach elevation antenna offset* shall represent the minimum distance between the elevation antenna phase centre and the vertical plane containing the runway centre line.

f) *Back azimuth next function* shall indicate that the next function to be transmitted is back azimuth.

g) *Minimum glide path* shall represent the minimum glide path as defined in 3.11.1 above.

h) *Beamwidth* shall represent, for a particular function, the antenna beamwidth as defined to the nearest least significant bit provided for in the data word.

i) *Approach azimuth sector guidance alert* shall represent the elevation angle in the specified azimuth sector below which guidance is unreliable or unsafe. A binary code "0" in this message element shall indicate that all approach azimuth angles in a particular sector are usable.

j) *DME distance* shall represent the distance measured parallel to the runway centre line from the DME antenna phase centre to the MLS datum point.

k) *DME offset* shall represent the minimum distance between the DME antenna phase centre and a vertical plane containing the runway centre line.

l) *DME channel* shall represent the DME channel associated with the selected MLS channel.

m) *Approach azimuth antenna offset* shall represent the minimum distance between the approach azimuth antenna phase centre and a vertical plane containing the runway centre line.

* The exact use of this element is not yet defined.

n) *MLS ground equipment identification* shall represent the last 3 characters of the system identification specified in 3.11.4.6.2.1 above. The characters shall be encoded in accordance with the 5-unit code of the International Telegraph Alphabet No. 2. Even character parity shall also be provided.

Note.— Restriction of data content to alphabetic characters eliminates the need for transmission of signal numbers 29 and 30 designating letters and figures.

o) *Back azimuth antenna distance* shall represent the horizontal distance measured parallel to the runway centre line from the back azimuth antenna phase centre to the back azimuth reference datum.

p) *Back azimuth proportional coverage limit* shall represent the limit of the sector in which proportional back azimuth guidance is transmitted.

q) *DME status* shall represent the operational status of the equipment in use.

r) *DME* or *DME/P* shall represent whether the equipment in use is DME or DME/P.

s) *MLS datum point to threshold distance* shall represent the distance measured along the runway centre line from the MLS datum point to the runway threshold.

t) *Clearance signal type* shall indicate the method of providing the azimuth clearance signal.

3.11.4.8.3 *Auxiliary data organization and timing.* Auxiliary data shall be organized into 64-bit words consisting of a preamble, address, information bits and parity bits. Two auxiliary data word formats shall be provided, one for digital data and one for alphanumeric character data. The timing of the auxiliary data function shall be as specified in Appendix A to Part I, Table A-8. Data containing digital information shall be transmitted with the least significant bit first. Alphanumeric data characters shall be encoded in accordance with International Alphabet No. 5 (IA-5) in Part I, 4.12.1.2 using seven information bits, plus one even parity bit added to each character. Alphanumeric data shall be transmitted in the order in which they are to be read. The serial transmission of a character shall be with the lower order bit transmitted first and the parity bit transmitted last. When provided, auxiliary data shall be transmitted between the function sequences.

Note.— The contents of the auxiliary data words are not yet defined.

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 over-all 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 to Part I, 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.— 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. At the same time, the reference datum provides a convenient point at which the accuracy and other parameters of the function may be specified.

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.* 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 below except where degradation is allowed as specified in 3.11.4.9.4.3 below.

3.11.4.9.4.3 *Degradation allowance.* 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, are 2 times the value specified at the approach reference datum. The CMN limit, expressed in angular terms at 18.5 km (10 NM) from the reference datum along the extended runway centre line is 1.3 times the value specified at the approach reference datum.

b) *With azimuth angle.* The PFE limit and PFN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, are 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, are 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.

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, are 2 times the value specified at the back azimuth reference datum. The CMN limit, expressed in angular terms at 9.27 km (5 NM) from the runway stop end along the extended runway centre line is 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, are 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 is 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, are 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.

3.11.4.9.6 *Elevation guidance function.* For equipment sited to provide a minimum glide path of nominally 3 degrees or lower, 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.* 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, are 0.2 degree. The CMN limit, expressed in angular terms at 18.5 km (10 NM) from the reference datum on the minimum glide path is 1.3 times the value specified at the approach reference datum.

b) *With azimuth angle.* The PFE limit and PFN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, are 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 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.* 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) 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 c) 2) below, 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.

3.11.4.9.6.2 **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. For other regions of coverage within the angular sector from an elevation angle equivalent to 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) above shall apply. The PFE should not exceed 0.35 degree, and the CMN should not exceed 0.2 degree.*

3.11.4.9.6.3 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.

3.11.4.9.7 *Flare elevation guidance function.* At the approach reference datum the flare elevation function shall provide performance 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). In no case shall the CMN exceed plus or minus 0.07 degree.

Note.— Degradation allowances for flare elevation have not yet been defined.

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 below.

Function	*DPSK signals (dBW/m²)*	*Angle signals (dBW/m²) 1° (antenna beamwidth)*	*2°*	*3°*	*Clearance signals (dBW/m²)*
Approach azimuth guidance	−89.5	−88.0	−85.5	−82.0	−88.0
High rate approach azimuth guidance	−89.5	−88.0	−88.0	−86.8	−88.0
Back azimuth guidance	−81.0	−79.5	−77.0	−73.5	−79.5
Approach elevation guidance	−89.5	−88.0	−88.0	N/A	N/A

N/A = not applicable

Note 1.— Information relating to interpolation of power density requirements for other antenna beamwidths is provided in Attachment G to Part I, 2.6.2.5.

Note 2.— 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. above.

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 above 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 above to support auto-land operations. Attachment G to Part I 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 below 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 above.

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 above 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 below.

3.11.5.1.1 *Residual radiation of MLS functions.* The residual radiation of an MLS function at times when it should not be transmitting shall not adversely affect the reception of any other function.

Note.— The level of residual radiation permitted for a particular function is dependent on equipment siting and aircraft positions.

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 *Co-ordinate system.* Azimuth guidance information shall be radiated in either conical or planar co-ordinates.

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 0.7 beamwidth, but not more than 0.9 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 to Part I, 3.1 and 3.2.

3.11.5.2.2 *Coverage*

Note.— Diagrams illustrating the coverage requirements specified herein are contained in Attachment G to Part I, Figures G-5 and G-6.

3.11.5.2.2.1 *Approach azimuth.* 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) Horizontally within a sector plus or minus 40 degrees about the runway centre line originating at the MLS datum point and extending in the direction of the approach to 37 km (20 NM) from the runway threshold.

b) Vertically between:

1) a conical surface originating 2.5 m (8 ft) above the runway centre line at threshold inclined at 0.9 degree above the horizontal; and

2) a conical surface originating at the azimuth ground equipment antenna inclined at 15 degrees above the horizontal to a height of 6 000 m (20 000 ft).

Note 1.— Where intervening obstacles penetrate the 0.9 degree 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 coverage or use of out-of-coverage indication signals. Guidance material on the use of these techniques is contained in Attachment G to Part I, 8.

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 approach region.

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) above is given in Attachment G to Part I, 2.3.6.

Note 2.— When physical characteristics of the runway prevent the achievement of the Standard above, it is intended that guidance need not be provided at less than line-of-sight heights.

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

3.11.5.2.2.1.4 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.

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

3.11.5.2.2.1.6 The minimum proportional guidance sector shall be plus or minus 10 degrees about the runway centre line. Where the proportional guidance sector provided is less than the minimum lateral coverage specified in 3.11.5.2.2.1.1 a) above, clearance guidance shall be provided to maintain the over-all coverage sector specified in 3.11.5.2.2.1.1 above.

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 9.3 km (5 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 which 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 1 500 m (5 000 ft).

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

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

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

3.11.5.2.2.4 The minimum proportional guidance sector shall be plus or minus 10 degrees about the runway centre line. Where the proportional guidance sector provided is less than the lateral coverage specified in 3.11.5.2.2.2 a) above, clearance guidance shall be provided to maintain the over-all coverage sectors specified in 3.11.5.2.2.2 above.

Note.— Application information is provided in Attachment G to Part I, 2.3.4.

3.11.5.2.3 *Monitor and control*

3.11.5.2.3.1 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 above 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 above 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) the timing standards specified in 3.11.4.3.4 above are exceeded for a period of more than one second;

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

Note.— Guidance material is provided in Attachment G to Part I, 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 above. Attempts to clear a fault by resetting the primary ground equipment or by switching to standby ground equipment 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.

3.11.5.2.4 *Ground equipment accuracy.* 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 **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 to Part I, 2.5.2.

3.11.5.2.6 *Siting*

Note.— 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.

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 Standards and Recommended Practices 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.* Elevation ground equipment antennas shall produce a fan-shaped beam which 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 *Co-ordinate system.* Approach elevation and flare guidance information shall be radiated in conical co-ordinates.

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 0.7 beamwidth but not more than 0.9 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 to Part I, 3.1 and 3.2.

3.11.5.3.2 *Coverage*

Note.— Diagrams illustrating the coverage requirements specified herein are contained in Attachment G to Part I, Figures G-8 and G-9.

3.11.5.3.2.1 *Approach elevation.* The approach elevation ground equipment shall provide proportional guidance information in at least the following volume of space:

a) laterally within a sector originating at the MLS datum point which is at least equal to the proportional guidance sector provided by the approach azimuth ground equipment;

b) longitudinally from 75 m (250 ft) from the MLS datum point in the direction of the approach to 37 km (20 NM) from threshold;

c) vertically within the sector bounded by:

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

2) a conical surface originating at the MLS datum point and inclined 0.9 degree above the horizontal; and

3) a conical surface originating at the MLS datum point 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) 2) above, it is intended that guidance need not be provided below a conical surface originating at the elevation antenna and inclined 0.9 degree above the line of sight.

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

3.11.5.3.2.3 *Flare elevation.* The flare elevation ground equipment shall provide proportional guidance information in at least the following volume of space:

a) horizontally over the runway surface and within a sector of plus or minus 10 degrees about the runway centre line originating at a point on the runway 760 m (2 500 ft) from threshold and extending to 9.3 km (5 NM) from threshold in the direction of the approach;

b) vertically within the sector bounded by:

1) surfaces which are the locus of points 2.5 m (8 ft) and 45 m (150 ft) above the runway;

2) a conical surface originating 2.5 m (8 ft) above the runway centre line at the threshold inclined 0.9 degree above the horizontal; and

3) a conical surface originating 760 m (2 500 ft) from threshold in the direction of the stop end and inclined 7.5 degrees above the horizontal up to 1 300 m (4 300 ft).

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

3.11.5.3.3 *Monitor and control*

3.11.5.3.3.1 The approach elevation and flare elevation monitor systems shall cause the radiation of their 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 and 3.11.4.9.7 above 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 above 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) the timing standards specified in 3.11.4.3.4 above are exceeded for a period of more than one second;

e) there is an error in the TDM synchronization of a particular elevation function such that the requirement

specified in 3.11.4.3.2 above is not satisfied and this condition persists for more than one second.

Note.— Guidance material is contained in Attachment G to Part I, 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 above. Attempts to clear a fault by resetting the primary ground equipment or by switching to standby ground equipment shall be completed within this time. 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 *Ground equipment accuracy.* 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.

3.11.5.3.4.1 **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 to Part I, 2.5.2.

3.11.5.3.5 *Siting*

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

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

3.11.5.3.5.2.1 **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.

3.11.5.3.5.3 **Recommendation.—** *When ILS and MLS simultaneously serve the same runway, the ILS and minimum MLS glide paths should be coincident over the threshold 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 above.

Note 2.— Information related to collocated MLS/ILS siting is provided in Attachment G to Part I, 4.

3.11.5.3.5.4 **Recommendation.—** *The flare ground equipment antenna should be located about 1 000 m (3 300 ft) from threshold in the direction of the stop end of the runway.*

3.11.5.4 *Data*

3.11.5.4.1 The basic data comprised in the words 1 to 6 inclusive and 8 shall be transmitted throughout the approach azimuth coverage sector. The basic data comprised in the words 6 and 7 shall be transmitted throughout the back azimuth sector.

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

3.11.5.4.2 *Monitor and control.* 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 above. If a detected error in a data word persists, radiation of that word shall cease.

3.11.5.4.3 *Auxiliary data*

Note.— Auxiliary data specifications and coverage have not yet been defined.

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.

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 G to Part I, 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 above, the airborne equipment shall be able to acquire the signal and any decoded angle signal shall have a CMN not exceeding 0.2 degree.

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) above.

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 above 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 above 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 above 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 to Part I, 7.4.2.

3.11.6.1.4 *Adjacent channel spurious response.* The receiver performance specified in 3.11.6 above shall be met when a desired signal is being tracked in the presence of an adjacent channel signal that is 25 dB stronger.

3.11.6.2 *Distance measuring function*

Note.— Text for this section is under study.

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 no.	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel no.*	*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
∇ 17X	108.00	–	–	1 041	12	–	–	978	12
17Y	108.05	5 043.0	540	1 041	36	36	42	1 104	30
17Z	–	5 043.3	541	1 041	–	21	27	1 104	15
18X	108.10	5 031.0	500	1 042	12	12	18	979	12
18W	–	5 031.3	501	1 042	–	24	30	979	24
18Y	108.15	5 043.6	542	1 042	36	36	42	1 105	30
18Z	–	5 043.9	543	1 042	–	21	27	1 105	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N μs	Initial approach μs	Final approach μs	Frequency MHz	Pulse codes μs
19X	108.20	–	–	1 043	12	–	–	980	12
19Y	108.25	5 044.2	544	1 043	36	36	42	1 106	30
19Z	–	5 044.5	545	1 043	–	21	27	1 106	15
20X	108.30	5 031.6	502	1 044	12	12	18	981	12
20W	–	5 031.9	503	1 044	–	24	30	981	24
20Y	108.35	5 044.8	546	1 044	36	36	42	1 107	30
20Z	–	5 045.1	547	1 044	–	21	27	1 107	15
21X	108.40	–	–	1 045	12	–	–	982	12
21Y	108.45	5 045.4	548	1 045	36	36	42	1 108	30
21Z	–	5 045.7	549	1 045	–	21	27	1 108	15
22X	108.50	5 032.2	504	1 046	12	12	18	983	12
22W	–	5 032.5	505	1 046	–	24	30	983	24
22Y	108.55	5 046.0	550	1 046	36	36	42	1 109	30
22Z	–	5 046.3	551	1 046	–	21	27	1 109	15
23X	108.60	–	–	1 047	12	–	–	984	12
23Y	108.65	5 046.6	552	1 047	36	36	42	1 110	30
23Z	–	5 046.9	553	1 047	–	21	27	1 110	15
24X	108.70	5 032.8	506	1 048	12	12	18	985	12
24W	–	5 033.1	507	1 048	–	24	30	985	24
24Y	108.75	5 047.2	554	1 048	36	36	42	1 111	30
24Z	–	5 047.5	555	1 048	–	21	27	1 111	15
25X	108.80	–	–	1 049	12	–	–	986	12
25Y	108.85	5 047.8	556	1 049	36	36	42	1 112	30
25Z	–	5 048.1	557	1 049	–	21	27	1 112	15
26X	108.90	5 033.4	508	1 050	12	12	18	987	12
26W	–	5 033.7	509	1 050	–	24	30	987	24
26Y	108.95	5 048.4	558	1 050	36	36	42	1 113	30
26Z	–	5 048.7	559	1 050	–	21	27	1 113	15
27X	109.00	–	–	1 051	12	–	–	988	12
27Y	109.05	5 049.0	560	1 051	36	36	42	1 114	30
27Z	–	5 049.3	561	1 051	–	21	27	1 114	15
28X	109.10	5 034.0	510	1 052	12	12	18	989	12
28W	–	5 034.3	511	1 052	–	24	30	989	24
28Y	109.15	5 049.6	562	1 052	36	36	42	1 115	30
28Z	–	5 049.9	563	1 052	–	21	27	1 115	15
29X	109.20	–	–	1 053	12	–	–	990	12
29Y	109.25	5 050.2	564	1 053	36	36	42	1 116	30
29Z	–	5 050.5	565	1 053	–	21	27	1 116	15
30X	109.30	5 034.6	512	1 054	12	12	18	991	12
30W	–	5 034.9	513	1 054	–	24	30	991	24
30Y	109.35	5 050.8	566	1 054	36	36	42	1 117	30
30Z	–	5 051.1	567	1 054	–	21	27	1 117	15
31X	109.40	–	–	1 055	12	–	–	992	12
31Y	109.45	5 051.4	568	1 055	36	36	42	1 118	30
31Z	–	5 051.7	569	1 055	–	21	27	1 118	15
32X	109.50	5 035.2	514	1 056	12	12	18	993	12
32W	–	5 035.5	515	1 056	–	24	30	993	24

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
32Y	109.55	5 052.0	570	1 056	36	36	42	1 119	30
32Z	-	5 052.3	571	1 056	-	21	27	1 119	15
33X	109.60	-	-	1 057	12	-	-	994	12
33Y	109.65	5 052.6	572	1 057	36	36	42	1 120	30
33Z	-	5 052.9	573	1 057	-	21	27	1 120	15
34X	109.70	5 035.8	516	1 058	12	12	18	995	12
34W	-	5 036.1	517	1 058	-	24	30	995	24
34Y	109.75	5 053.2	574	1 058	36	36	42	1 121	30
34Z	-	5 053.5	575	1 058	-	21	27	1 121	15
35X	109.80	-	-	1 059	12	-	-	996	12
35Y	109.85	5 053.8	576	1 059	36	36	42	1 122	30
35Z	-	5 054.1	577	1 059	-	21	27	1 122	15
36X	109.90	5 036.4	518	1 060	12	12	18	997	12
36W	-	5 036.7	519	1 060	-	24	30	997	24
36Y	109.95	5 054.4	578	1 060	36	36	42	1 123	30
36Z	-	5 054.7	579	1 060	-	21	27	1 123	15
37X	110.00	-	-	1 061	12	-	-	998	12
37Y	110.05	5 055.0	580	1 061	36	36	42	1 124	30
37Z	-	5 055.3	581	1 061	-	21	27	1 124	15
38X	110.10	5 037.0	520	1 062	12	12	18	999	12
38W	-	5 037.3	521	1 062	-	24	30	999	24
38Y	110.15	5 055.6	582	1 062	36	36	42	1 125	30
38Z	-	5 055.9	583	1 062	-	21	27	1 125	15
39X	110.20	-	-	1 063	12	-	-	1 000	12
39Y	110.25	5 056.2	584	1 063	36	36	42	1 126	30
39Z	-	5 056.5	585	1 063	-	21	27	1 126	15
40X	110.30	5 037.6	522	1 064	12	12	18	1 001	12
40W	-	5 037.9	523	1 064	-	24	30	1 001	24
40Y	110.35	5 056.8	586	1 064	36	36	42	1 127	30
40Z	-	5 057.1	587	1 064	-	21	27	1 127	15
41X	110.40	-	-	1 065	12	-	-	1 002	12
41Y	110.45	5 057.4	588	1 065	36	36	42	1 128	30
41Z	-	5 057.7	589	1 065	-	21	27	1 128	15
42X	110.50	5 038.2	524	1 066	12	12	18	1 003	12
42W	-	5 038.5	525	1 066	-	24	30	1 003	24
42Y	110.55	5 058.0	590	1 066	36	36	42	1 129	30
42Z	-	5 058.3	591	1 066	-	21	27	1 129	15
43X	110.60	-	-	1 067	12	-	-	1 004	12
43Y	110.65	5 058.6	592	1 067	36	36	42	1 130	30
43Z	-	5 058.9	593	1 067	-	21	27	1 130	15
44X	110.70	5 038.8	526	1 068	12	12	18	1 005	12
44W	-	5 039.1	527	1 068	-	24	30	1 005	24
44Y	110.75	5 059.2	594	1 068	36	36	42	1 131	30
44Z	-	5 059.5	595	1 068	-	21	27	1 131	15
45X	110.80	-	-	1 069	12	-	-	1 006	12
45Y	110.85	5 059.8	596	1 069	36	36	42	1 132	30
45Z	-	5 060.1	597	1 069	-	21	27	1 132	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
46X	110.90	5 039.4	528	1 070	12	12	18	1 007	12
46W	-	5 039.7	529	1 070	-	24	30	1 007	24
46Y	110.95	5 060.4	598	1 070	36	36	42	1 133	30
46Z	-	5 060.7	599	1 070	-	21	27	1 133	15
47X	111.00	-	-	1 071	12	-	-	1 008	12
47Y	111.05	5 061.0	600	1 071	36	36	42	1 134	30
47Z	-	5 061.3	601	1 071	-	21	27	1 134	15
48X	111.10	5 040.0	530	1 072	12	12	18	1 009	12
48W	-	5 040.3	531	1 072	-	24	30	1 009	24
48Y	111.15	5 061.6	602	1 072	36	36	42	1 135	30
48Z	-	5 061.9	603	1 072	-	21	27	1 135	15
49X	111.20	-	-	1 073	12	-	-	1 010	12
49Y	111.25	5 062.2	604	1 073	36	36	42	1 136	30
49Z	-	5 062.5	605	1 073	-	21	27	1 136	15
50X	111.30	5 040.6	532	1 074	12	12	18	1 011	12
50W	-	5 040.9	533	1 074	-	24	30	1 011	24
50Y	111.35	5 062.8	606	1 074	36	36	42	1 137	30
50Z	-	5 063.1	607	1 074	-	21	27	1 137	15
51X	111.40	-	-	1 075	12	-	-	1 012	12
51Y	111.45	5 063.4	608	1 075	36	36	42	1 138	30
51Z	-	5 063.7	609	1 075	-	21	27	1 138	15
52X	111.50	5 041.2	534	1 076	12	12	18	1 013	12
52W	-	5 041.5	535	1 076	-	24	30	1 013	24
52Y	111.55	5 064.0	610	1 076	36	36	42	1 139	30
52Z	-	5 064.3	611	1 076	-	21	27	1 139	15
53X	111.60	-	-	1 077	12	-	-	1 014	12
53Y	111.65	5 064.6	612	1 077	36	36	42	1 140	30
53Z	-	5 064.9	613	1 077	-	21	27	1 140	15
54X	111.70	5 041.8	536	1 078	12	12	18	1 015	12
54W	-	5 042.1	537	1 078	-	24	30	1 015	24
54Y	111.75	5 065.2	614	1 078	36	36	42	1 141	30
54Z	-	5 065.5	615	1 078	-	21	27	1 141	15
55X	111.80	-	-	1 079	12	-	-	1 016	12
55Y	111.85	5 065.8	616	1 079	36	36	42	1 142	30
55Z	-	5 066.1	617	1 079	-	21	27	1 142	15
56X	111.90	5 042.4	538	1 080	12	12	18	1 017	12
56W	-	5 042.7	539	1 080	-	24	30	1 017	24
56Y	111.95	5 066.4	618	1 080	36	36	42	1 143	30
56Z	-	5 066.7	619	1 080	-	21	27	1 143	15
57X	112.00	-	-	1 081	12	-	-	1 018	12
57Y	112.05	-	-	1 081	36	-	-	1 144	30
58X	112.10	-	-	1 082	12	-	-	1 019	12
58Y	112.15	-	-	1 082	36	-	-	1 145	30
59X	112.20	-	-	1 083	12	-	-	1 020	12
59Y	112.25	-	-	1 083	36	-	-	1 146	30
** 60X	-	-	-	1 084	12	-	-	1 021	12
** 60Y	-	-	-	1 084	36	-	-	1 147	30

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
** 61X	-	-	-	1 085	12	-	-	1 022	12
** 61Y	-	-	-	1 085	36	-	-	1 148	30
** 62X	-	-	-	1 086	12	-	-	1 023	12
** 62Y	-	-	-	1 086	36	-	-	1 149	30
** 63X	-	-	-	1 087	12	-	-	1 024	12
** 63Y	-	-	-	1 087	36	-	-	1 150	30
** 64X	-	-	-	1 088	12	-	-	1 151	12
** 64Y	-	-	-	1 088	36	-	-	1 025	30
** 65X	-	-	-	1 089	12	-	-	1 152	12
** 65Y	-	-	-	1 089	36	-	-	1 026	30
** 66X	-	-	-	1 090	12	-	-	1 153	12
** 66Y	-	-	-	1 090	36	-	-	1 027	30
** 67X	-	-	-	1 091	12	-	-	1 154	12
** 67Y	-	-	-	1 091	36	-	-	1 028	30
** 68X	-	-	-	1 092	12	-	-	1 155	12
** 68Y	-	-	-	1 092	36	-	-	1 029	30
** 69X	-	-	-	1 093	12	-	-	1 156	12
** 69Y	-	-	-	1 093	36	-	-	1 030	30
70X	112.30	-	-	1 094	12	-	-	1 157	12
** 70Y	112.35	-	-	1 094	36	-	-	1 031	30
71X	112.40	-	-	1 095	12	-	-	1 158	12
** 71Y	112.45	-	-	1 095	36	-	-	1 032	30
72X	112.50	-	-	1 096	12	-	-	1 159	12
** 72Y	112.55	-	-	1 096	36	-	-	1 033	30
73X	112.60	-	-	1 097	12	-	-	1 160	12
** 73Y	112.65	-	-	1 097	36	-	-	1 034	30
74X	112.70	-	-	1 098	12	-	-	1 161	12
** 74Y	112.75	-	-	1 098	36	-	-	1 035	30
75X	112.80	-	-	1 099	12	-	-	1 162	12
** 75Y	112.85	-	-	1 099	36	-	-	1 036	30
76X	112.90	-	-	1 100	12	-	-	1 163	12
** 76Y	112.95	-	-	1 100	36	-	-	1 037	30
77X	113.00	-	-	1 101	12	-	-	1 164	12
** 77Y	113.05	-	-	1 101	36	-	-	1 038	30
78X	113.10	-	-	1 102	12	-	-	1 165	12
** 78Y	113.15	-	-	1 102	36	-	-	1 039	30
79X	113.20	-	-	1 103	12	-	-	1 166	12
** 79Y	113.25	-	-	1 103	36	-	-	1 040	30
80X	113.30	-	-	1 104	12	-	-	1 167	12
80Y	113.35	5 067.0	620	1 104	36	36	42	1 041	30
80Z	-	5 067.3	621	1 104	-	21	27	1 041	15
81X	113.40	-	-	1 105	12	-	-	1 168	12
81Y	113.45	5 067.6	622	1 105	36	36	42	1 042	30
81Z	-	5 067.9	623	1 105	-	21	27	1 042	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
82X	113.50	-	-	1 106	12	-	-	1 169	12
82Y	113.55	5 068.2	624	1 106	36	36	42	1 043	30
82Z	-	5 068.5	625	1 106	-	21	27	1 043	15
83X	113.60	-	-	1 107	12	-	-	1 170	12
83Y	113.65	5 068.8	626	1 107	36	36	42	1 044	30
83Z	-	5 069.1	627	1 107	-	21	27	1 044	15
84X	113.70	-	-	1 108	12	-	-	1 171	12
84Y	113.75	5 069.4	628	1 108	36	36	42	1 045	30
84Z	-	5 069.7	629	1 108	-	21	27	1 045	15
85X	113.80	-	-	1 109	12	-	-	1 172	12
85Y	113.85	5 070.0	630	1 109	36	36	42	1 046	30
85Z	-	5 070.3	631	1 109	-	21	27	1 046	15
86X	113.90	-	-	1 110	12	-	-	1 173	12
86Y	113.95	5 070.6	632	1 110	36	36	42	1 047	30
86Z	-	5 070.9	633	1 110	-	21	27	1 047	15
87X	114.00	-	-	1 111	12	-	-	1 174	12
87Y	114.05	5 071.2	634	1 111	36	36	42	1 048	30
87Z	-	5 071.5	635	1 111	-	21	27	1 048	15
88X	114.10	-	-	1 112	12	-	-	1 175	12
88Y	114.15	5 071.8	636	1 112	36	36	42	1 049	30
88Z	-	5 072.1	637	1 112	-	21	27	1 049	15
89X	114.20	-	-	1 113	12	-	-	1 176	12
89Y	114.25	5 072.4	638	1 113	36	36	42	1 050	30
89Z	-	5 072.7	639	1 113	-	21	27	1 050	15
90X	114.30	-	-	1 114	12	-	-	1 177	12
90Y	114.35	5 073.0	640	1 114	36	36	42	1 051	30
90Z	-	5 073.3	641	1 114	-	21	27	1 051	15
91X	114.40	-	-	1 115	12	-	-	1 178	12
91Y	114.45	5 073.6	642	1 115	36	36	42	1 052	30
91Z	-	5 073.9	643	1 115	-	21	27	1 052	15
92X	114.50	-	-	1 116	12	-	-	1 179	12
92Y	114.55	5 074.2	644	1 116	36	36	42	1 053	30
92Z	-	5 074.5	645	1 116	-	21	27	1 053	15
93X	114.60	-	-	1 117	12	-	-	1 180	12
93Y	114.65	5 074.8	646	1 117	36	36	42	1 054	30
93Z	-	5 075.1	647	1 117	-	21	27	1 054	15
94X	114.70	-	-	1 118	12	-	-	1 181	12
94Y	114.75	5 075.4	648	1 118	36	36	42	1 055	30
94Z	-	5 075.7	649	1 118	-	21	27	1 055	15
95X	114.80	-	-	1 119	12	-	-	1 182	12
95Y	114.85	5 076.0	650	1 119	36	36	42	1 056	30
95Z	-	5 076.3	651	1 119	-	21	27	1 056	15
96X	114.90	-	-	1 120	12	-	-	1 183	12
96Y	114.95	5 076.6	652	1 120	36	36	42	1 057	30
96Z	-	5 076.9	653	1 120	-	21	27	1 057	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
97X	115.00	-	-	1 121	12	-	-	1 184	12
97Y	115.05	5 077.2	654	1 121	36	36	42	1 058	30
97Z	-	5 077.5	655	1 121	-	21	27	1 058	15
98X	115.10	-	-	1 122	12	-	-	1 185	12
98Y	115.15	5 077.8	656	1 122	36	36	42	1 059	30
98Z	-	5 078.1	657	1 122	-	21	27	1 059	15
99X	115.20	-	-	1 123	12	-	-	1 186	12
99Y	115.25	5 078.4	658	1 123	36	36	42	1 060	30
99Z	-	5 078.7	659	1 123	-	21	27	1 060	15
100X	115.30	-	-	1 124	12	-	-	1 187	12
100Y	115.35	5 079.0	660	1 124	36	36	42	1 061	30
100Z	-	5 079.3	661	1 124	-	21	27	1 061	15
101X	115.40	-	-	1 125	12	-	-	1 188	12
101Y	115.45	5 079.6	662	1 125	36	36	42	1 062	30
101Z	-	5 079.9	663	1 125	-	21	27	1 062	15
102X	115.50	-	-	1 126	12	-	-	1 189	12
102Y	115.55	5 080.2	664	1 126	36	36	42	1 063	30
102Z	-	5 080.5	665	1 126	-	21	27	1 063	15
103X	115.60	-	-	1 127	12	-	-	1 190	12
103Y	115.65	5 080.8	666	1 127	36	36	42	1 064	30
103Z	-	5 081.1	667	1 127	-	21	27	1 064	15
104X	115.70	-	-	1 128	12	-	-	1 191	12
104Y	115.75	5 081.4	668	1 128	36	36	42	1 065	30
104Z	-	5 081.7	669	1 128	-	21	27	1 065	15
105X	115.80	-	-	1 129	12	-	-	1 192	12
105Y	115.85	5 082.0	670	1 129	36	36	42	1 066	30
105Z	-	5 082.3	671	1 129	-	21	27	1 066	15
106X	115.90	-	-	1 130	12	-	-	1 193	12
106Y	115.95	5 082.6	672	1 130	36	36	42	1 067	30
106Z	-	5 082.9	673	1 130	-	21	27	1 067	15
107X	116.00	-	-	1 131	12	-	-	1 194	12
107Y	116.05	5 083.2	674	1 131	36	36	42	1 068	30
107Z	-	5 083.5	675	1 131	-	21	27	1 068	15
108X	116.10	-	-	1 132	12	-	-	1 195	12
108Y	116.15	5 083.8	676	1 132	36	36	42	1 069	30
108Z	-	5 084.1	677	1 132	-	21	27	1 069	15
109X	116.20	-	-	1 133	12	-	-	1 196	12
109Y	116.25	5 084.4	678	1 133	36	36	42	1 070	30
109Z	-	5 084.7	679	1 133	-	21	27	1 070	15
110X	116.30	-	-	1 134	12	-	-	1 197	12
110Y	116.35	5 085.0	680	1 134	36	36	42	1 071	30
110Z	-	5 085.3	681	1 134	-	21	27	1 071	15
111X	116.40	-	-	1 135	12	-	-	1 198	12
111Y	116.45	5 085.6	682	1 135	36	36	42	1 072	30
111Z	-	5 085.9	683	1 135	-	21	27	1 072	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME no.	VHF frequency MHz	MLS angle frequency MHz	MLS channel no.	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
112X	116.50	-	-	1 136	12	-	-	1 199	12
112Y	116.55	5 086.2	684	1 136	36	36	42	1 073	30
112Z	-	5 086.5	685	1 136	-	21	27	1 073	15
113X	116.60	-	-	1 137	12	-	-	1 200	12
113Y	116.65	5 086.8	686	1 137	36	36	42	1 074	30
113Z	-	5 087.1	687	1 137	-	21	27	1 074	15
114X	116.70	-	-	1 138	12	-	-	1 201	12
114Y	116.75	5 087.4	688	1 138	36	36	42	1 075	30
114Z	-	5 087.7	689	1 138	-	21	27	1 075	15
115X	116.80	-	-	1 139	12	-	-	1 202	12
115Y	116.85	5 088.0	690	1 139	36	36	42	1 076	30
115Z	-	5 088.3	691	1 139	-	21	27	1 076	15
116X	116.90	-	-	1 140	12	-	-	1 203	12
116Y	116.95	5 088.6	692	1 140	36	36	42	1 077	30
116Z	-	5 088.9	693	1 140	-	21	27	1 077	15
117X	117.00	-	-	1 141	12	-	-	1 204	12
117Y	117.05	5 089.2	694	1 141	36	36	42	1 078	30
117Z	-	5 089.5	695	1 141	-	21	27	1 078	15
118X	117.10	-	-	1 142	12	-	-	1 205	12
118Y	117.15	5 089.8	696	1 142	36	36	42	1 079	30
118Z	-	5 090.1	697	1 142	-	21	27	1 079	15
119X	117.20	-	-	1 143	12	-	-	1 206	12
119Y	117.25	5 090.4	698	1 143	36	36	42	1 080	30
119Z	-	5 090.7	699	1 143	-	21	27	1 080	15
120X	117.30	-	-	1 144	12	-	-	1 207	12
120Y	117.35	-	-	1 144	36	-	-	1 081	30
121X	117.40	-	-	1 145	12	-	-	1 208	12
121Y	117.45	-	-	1 145	36	-	-	1 082	30
122X	117.50	-	-	1 146	12	-	-	1 209	12
122Y	117.55	-	-	1 146	36	-	-	1 083	30
123X	117.60	-	-	1 147	12	-	-	1 210	12
123Y	117.65	-	-	1 147	36	-	-	1 084	30
124X	117.70	-	-	1 148	12	-	-	1 211	12
** 124Y	117.75	-	-	1 148	36	-	-	1 085	30
125X	117.80	-	-	1 149	12	-	-	1 212	12
** 125Y	117.85	-	-	1 149	36	-	-	1 086	30
126X	117.90	-	-	1 150	12	-	-	1 213	12
** 126Y	117.95	-	-	1 150	36	-	-	1 087	30

* These channels are reserved exclusively for national allotments.

** These channels may be used for national allotment on a secondary basis.
The primary reason for reserving these channels is to provide protection for the secondary surveillance radar (SSR) system.

∇ 108.0 MHz is not scheduled for assignment to ILS service. The associated DME operating channel No. 17X may be assigned for emergency use.

Table B. SSR automatic pressure altitude transmission code (pulse position assignment)

RANGE			PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
-1 000	to	-950	0	0	0	0	0	0	0	0	0	1	0
-950	to	-850	0	0	0	0	0	0	0	0	1	1	0
-850	to	-750	0	0	0	0	0	0	0	0	1	0	0
-750	to	-650	0	0	0	0	0	0	0	1	1	0	0
-650	to	-550	0	0	0	0	0	0	0	1	1	1	0
-550	to	-450	0	0	0	0	0	0	0	1	0	1	0
-450	to	-350	0	0	0	0	0	0	0	1	0	1	1
-350	to	-250	0	0	0	0	0	0	0	1	0	0	1
-250	to	-150	0	0	0	0	0	0	1	1	0	0	1
-150	to	-50	0	0	0	0	0	0	1	1	0	1	1
-50	to	50	0	0	0	0	0	0	1	1	0	1	0
50	to	150	0	0	0	0	0	0	1	1	1	1	0
150	to	250	0	0	0	0	0	0	1	1	1	0	0
250	to	350	0	0	0	0	0	0	1	0	1	0	0
350	to	450	0	0	0	0	0	0	1	0	1	1	0
450	to	550	0	0	0	0	0	0	1	0	0	1	0
550	to	650	0	0	0	0	0	0	1	0	0	1	1
650	to	750	0	0	0	0	0	0	1	0	0	0	1
750	to	850	0	0	0	0	0	1	1	0	0	0	1
850	to	950	0	0	0	0	0	1	1	0	0	1	1
950	to	1 050	0	0	0	0	0	1	1	0	0	1	0
1 050	to	1 150	0	0	0	0	0	1	1	0	1	1	0
1 150	to	1 250	0	0	0	0	0	1	1	0	1	0	0
1 250	to	1 350	0	0	0	0	0	1	1	1	1	0	0
1 350	to	1 450	0	0	0	0	0	1	1	1	1	1	0
1 450	to	1 550	0	0	0	0	0	1	1	1	0	1	0
1 550	to	1 650	0	0	0	0	0	1	1	1	0	1	1
1 650	to	1 750	0	0	0	0	0	1	1	1	0	0	1
1 750	to	1 850	0	0	0	0	0	1	0	1	0	0	1
1 850	to	1 950	0	0	0	0	0	1	0	1	0	1	1
1 950	to	2 050	0	0	0	0	0	1	0	1	0	1	0
2 050	to	2 150	0	0	0	0	0	1	0	1	1	1	0
2 150	to	2 250	0	0	0	0	0	1	0	1	1	0	0
2 250	to	2 350	0	0	0	0	0	1	0	0	1	0	0
2 350	to	2 450	0	0	0	0	0	1	0	0	1	1	0
2 450	to	2 550	0	0	0	0	0	1	0	0	0	1	0
2 550	to	2 650	0	0	0	0	0	1	0	0	0	1	1
2 650	to	2 750	0	0	0	0	0	1	0	0	0	0	1
2 750	to	2 850	0	0	0	0	1	1	0	0	0	0	1
2 850	to	2 950	0	0	0	0	1	1	0	0	0	1	1
2 950	to	3 050	0	0	0	0	1	1	0	0	0	1	0
3 050	to	3 150	0	0	0	0	1	1	0	0	1	1	0
3 150	to	3 250	0	0	0	0	1	1	0	0	1	0	0
3 250	to	3 350	0	0	0	0	1	1	0	1	1	0	0
3 350	to	3 450	0	0	0	0	1	1	0	1	1	1	0
3 450	to	3 550	0	0	0	0	1	1	0	1	0	1	0
3 550	to	3 650	0	0	0	0	1	1	0	1	0	1	1
3 650	to	3 750	0	0	0	0	1	1	0	1	0	0	1
3 750	to	3 850	0	0	0	0	1	1	1	1	0	0	1
3 850	to	3 950	0	0	0	0	1	1	1	1	0	1	1
3 950	to	4 050	0	0	0	0	1	1	1	1	0	1	0
4 050	to	4 150	0	0	0	0	1	1	1	1	1	1	0
4 150	to	4 250	0	0	0	0	1	1	1	1	1	0	0
4 250	to	4 350	0	0	0	0	1	1	1	0	1	0	0
4 350	to	4 450	0	0	0	0	1	1	1	0	1	1	0
4 450	to	4 550	0	0	0	0	1	1	1	0	0	1	0
4 550	to	4 650	0	0	0	0	1	1	1	0	0	1	1
4 650	to	4 750	0	0	0	0	1	1	1	0	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
4 750 to 4 850	0	0	0	0	1	0	1	0	0	0	1
4 850 to 4 950	0	0	0	0	1	0	1	0	0	1	1
4 950 to 5 050	0	0	0	0	1	0	1	0	0	1	0
5 050 to 5 150	0	0	0	0	1	0	1	0	1	1	0
5 150 to 5 250	0	0	0	0	1	0	1	0	1	0	0
5 250 to 5 350	0	0	0	0	1	0	1	1	1	0	0
5 350 to 5 450	0	0	0	0	1	0	1	1	1	1	0
5 450 to 5 550	0	0	0	0	1	0	1	1	0	1	0
5 550 to 5 650	0	0	0	0	1	0	1	1	0	1	1
5 650 to 5 750	0	0	0	0	1	0	1	1	0	0	1
5 750 to 5 850	0	0	0	0	1	0	0	1	0	0	1
5 850 to 5 950	0	0	0	0	1	0	0	1	0	1	1
5 950 to 6 050	0	0	0	0	1	0	0	1	0	1	0
6 050 to 6 150	0	0	0	0	1	0	0	1	1	1	0
6 150 to 6 250	0	0	0	0	1	0	0	1	1	0	0
6 250 to 6 350	0	0	0	0	1	0	0	0	1	0	0
6 350 to 6 450	0	0	0	0	1	0	0	0	1	1	0
6 450 to 6 550	0	0	0	0	1	0	0	0	0	1	0
6 550 to 6 650	0	0	0	0	1	0	0	0	0	1	1
6 650 to 6 750	0	0	0	0	1	0	0	0	0	0	1
6 750 to 6 850	0	0	0	1	1	0	0	0	0	0	1
6 850 to 6 950	0	0	0	1	1	0	0	0	0	1	1
6 950 to 7 050	0	0	0	1	1	0	0	0	0	1	0
7 050 to 7 150	0	0	0	1	1	0	0	0	1	1	0
7 150 to 7 250	0	0	0	1	1	0	0	0	1	0	0
7 250 to 7 350	0	0	0	1	1	0	0	1	1	0	0
7 350 to 7 450	0	0	0	1	1	0	0	1	1	1	0
7 450 to 7 550	0	0	0	1	1	0	0	1	0	1	0
7 550 to 7 650	0	0	0	1	1	0	0	1	0	1	1
7 650 to 7 750	0	0	0	1	1	0	0	1	0	0	1
7 750 to 7 850	0	0	0	1	1	0	1	1	0	0	1
7 850 to 7 950	0	0	0	1	1	0	1	1	0	1	1
7 950 to 8 050	0	0	0	1	1	0	1	1	0	1	0
8 050 to 8 150	0	0	0	1	1	0	1	1	1	1	0
8 150 to 8 250	0	0	0	1	1	0	1	1	1	0	0
8 250 to 8 350	0	0	0	1	1	0	1	0	1	0	0
8 350 to 8 450	0	0	0	1	1	0	1	0	1	1	0
8 450 to 8 550	0	0	0	1	1	0	1	0	0	1	0
8 550 to 8 650	0	0	0	1	1	0	1	0	0	1	1
8 650 to 8 750	0	0	0	1	1	0	1	0	0	0	1
8 750 to 8 850	0	0	0	1	1	1	1	0	0	0	1
8 850 to 8 950	0	0	0	1	1	1	1	0	0	1	1
8 950 to 9 050	0	0	0	1	1	1	1	0	0	1	0
9 050 to 9 150	0	0	0	1	1	1	1	0	1	1	0
9 150 to 9 250	0	0	0	1	1	1	1	0	1	0	0
9 250 to 9 350	0	0	0	1	1	1	1	1	1	0	0
9 350 to 9 450	0	0	0	1	1	1	1	1	1	1	0
9 450 to 9 550	0	0	0	1	1	1	1	1	0	1	0
9 550 to 9 650	0	0	0	1	1	1	1	1	0	1	1
9 650 to 9 750	0	0	0	1	1	1	1	1	0	0	1
9 750 to 9 850	0	0	0	1	1	1	0	1	0	0	1
9 850 to 9 950	0	0	0	1	1	1	0	1	0	1	1
9 950 to 10 050	0	0	0	1	1	1	0	1	0	1	0
10 050 to 10 150	0	0	0	1	1	1	0	1	1	1	0
10 150 to 10 250	0	0	0	1	1	1	0	1	1	0	0
10 250 to 10 350	0	0	0	1	1	1	0	0	1	0	0
10 350 to 10 450	0	0	0	1	1	1	0	0	1	1	0
10 450 to 10 550	0	0	0	1	1	1	0	0	0	1	0
10 550 to 10 650	0	0	0	1	1	1	0	0	0	1	1
10 650 to 10 750	0	0	0	1	1	1	0	0	0	0	1
10 750 to 10 850	0	0	0	1	0	1	0	0	0	0	1
10 850 to 10 950	0	0	0	1	0	1	0	0	0	1	1
10 950 to 11 050	0	0	0	1	0	1	0	0	0	1	0
11 050 to 11 150	0	0	0	1	0	1	0	0	1	1	0
11 150 to 11 250	0	0	0	1	0	1	0	0	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
11 250 to 11 350	0	0	0	1	0	1	0	1	1	0	0
11 350 to 11 450	0	0	0	1	0	1	0	1	1	1	0
11 450 to 11 550	0	0	0	1	0	1	0	1	0	1	0
11 550 to 11 650	0	0	0	1	0	1	0	1	0	1	1
11 650 to 11 750	0	0	0	1	0	1	0	1	0	0	1
11 750 to 11 850	0	0	0	1	0	1	1	1	0	0	1
11 850 to 11 950	0	0	0	1	0	1	1	1	0	1	1
11 950 to 12 050	0	0	0	1	0	1	1	1	0	1	0
12 050 to 12 150	0	0	0	1	0	1	1	1	1	1	0
12 150 to 12 250	0	0	0	1	0	1	1	1	1	0	0
12 250 to 12 350	0	0	0	1	0	1	1	0	1	0	0
12 350 to 12 450	0	0	0	1	0	1	1	0	1	1	0
12 450 to 12 550	0	0	0	1	0	1	1	0	0	1	0
12 550 to 12 650	0	0	0	1	0	1	1	0	0	1	1
12 650 to 12 750	0	0	0	1	0	1	1	0	0	0	1
12 750 to 12 850	0	0	0	1	0	0	1	0	0	0	1
12 850 to 12 950	0	0	0	1	0	0	1	0	0	1	1
12 950 to 13 050	0	0	0	1	0	0	1	0	0	1	0
13 050 to 13 150	0	0	0	1	0	0	1	0	1	1	0
13 150 to 13 250	0	0	0	1	0	0	1	0	1	0	0
13 250 to 13 350	0	0	0	1	0	0	1	1	1	0	0
13 350 to 13 450	0	0	0	1	0	0	1	1	1	1	0
13 450 to 13 550	0	0	0	1	0	0	1	1	0	1	0
13 550 to 13 650	0	0	0	1	0	0	1	1	0	1	1
13 650 to 13 750	0	0	0	1	0	0	1	1	0	0	1
13 750 to 13 850	0	0	0	1	0	0	0	1	0	0	1
13 850 to 13 950	0	0	0	1	0	0	0	1	0	1	1
13 950 to 14 050	0	0	0	1	0	0	0	1	0	1	0
14 050 to 14 150	0	0	0	1	0	0	0	1	1	1	0
14 150 to 14 250	0	0	0	1	0	0	0	1	1	0	0
14 250 to 14 350	0	0	0	1	0	0	0	0	1	0	0
14 350 to 14 450	0	0	0	1	0	0	0	0	1	1	0
14 450 to 14 550	0	0	0	1	0	0	0	0	0	1	0
14 550 to 14 650	0	0	0	1	0	0	0	0	0	1	1
14 650 to 14 750	0	0	0	1	0	0	0	0	0	0	1
14 750 to 14 850	0	0	1	1	0	0	0	0	0	0	1
14 850 to 14 950	0	0	1	1	0	0	0	0	0	1	1
14 950 to 15 050	0	0	1	1	0	0	0	0	0	1	0
15 050 to 15 150	0	0	1	1	0	0	0	0	1	1	0
15 150 to 15 250	0	0	1	1	0	0	0	0	1	0	0
15 250 to 15 350	0	0	1	1	0	0	0	1	1	0	0
15 350 to 15 450	0	0	1	1	0	0	0	1	1	1	0
15 450 to 15 550	0	0	1	1	0	0	0	1	0	1	0
15 550 to 15 650	0	0	1	1	0	0	0	1	0	1	1
15 650 to 15 750	0	0	1	1	0	0	0	1	0	0	1
15 750 to 15 850	0	0	1	1	0	0	1	1	0	0	1
15 850 to 15 950	0	0	1	1	0	0	1	1	0	1	1
15 950 to 16 050	0	0	1	1	0	0	1	1	0	1	0
16 050 to 16 150	0	0	1	1	0	0	1	1	1	1	0
16 150 to 16 250	0	0	1	1	0	0	1	1	1	0	0
16 250 to 16 350	0	0	1	1	0	0	1	0	1	0	0
16 350 to 16 450	0	0	1	1	0	0	1	0	1	1	0
16 450 to 16 550	0	0	1	1	0	0	1	0	0	1	0
16 550 to 16 650	0	0	1	1	0	0	1	0	0	1	1
16 650 to 16 750	0	0	1	1	0	0	1	0	0	0	1
16 750 to 16 850	0	0	1	1	0	1	1	0	0	0	1
16 850 to 16 950	0	0	1	1	0	1	1	0	0	1	1
16 950 to 17 050	0	0	1	1	0	1	1	0	0	1	0
17 050 to 17 150	0	0	1	1	0	1	1	0	1	1	0
17 150 to 17 250	0	0	1	1	0	1	1	0	1	0	0
17 250 to 17 350	0	0	1	1	0	1	1	1	1	0	0
17 350 to 17 450	0	0	1	1	0	1	1	1	1	1	0
17 450 to 17 550	0	0	1	1	0	1	1	1	0	1	0
17 550 to 17 650	0	0	1	1	0	1	1	1	0	1	1
17 650 to 17 750	0	0	1	1	0	1	1	1	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
17 750 to 17 850	0	0	1	1	0	1	0	1	0	0	1
17 850 to 17 950	0	0	1	1	0	1	0	1	0	1	1
17 950 to 18 050	0	0	1	1	0	1	0	1	0	1	0
18 050 to 18 150	0	0	1	1	0	1	0	1	1	1	0
18 150 to 18 250	0	0	1	1	0	1	0	1	1	0	0
18 250 to 18 350	0	0	1	1	0	1	0	0	1	0	0
18 350 to 18 450	0	0	1	1	0	1	0	0	1	1	0
18 450 to 18 550	0	0	1	1	0	1	0	0	0	1	0
18 550 to 18 650	0	0	1	1	0	1	0	0	0	1	1
18 650 to 18 750	0	0	1	1	0	1	0	0	0	0	1
18 750 to 18 850	0	0	1	1	1	1	0	0	0	0	1
18 850 to 18 950	0	0	1	1	1	1	0	0	0	1	1
18 950 to 19 050	0	0	1	1	1	1	0	0	0	1	0
19 050 to 19 150	0	0	1	1	1	1	0	0	1	1	0
19 150 to 19 250	0	0	1	1	1	1	0	0	1	0	0
19 250 to 19 350	0	0	1	1	1	1	0	1	1	0	0
19 350 to 19 450	0	0	1	1	1	1	0	1	1	1	0
19 450 to 19 550	0	0	1	1	1	1	0	1	0	1	0
19 550 to 19 650	0	0	1	1	1	1	0	1	0	1	1
19 650 to 19 750	0	0	1	1	1	1	0	1	0	0	1
19 750 to 19 850	0	0	1	1	1	1	1	1	0	0	1
19 850 to 19 950	0	0	1	1	1	1	1	1	0	1	1
19 950 to 20 050	0	0	1	1	1	1	1	1	0	1	0
20 050 to 20 150	0	0	1	1	1	1	1	1	1	1	0
20 150 to 20 250	0	0	1	1	1	1	1	1	1	0	0
20 250 to 20 350	0	0	1	1	1	1	1	0	1	0	0
20 350 to 20 450	0	0	1	1	1	1	1	0	1	1	0
20 450 to 20 550	0	0	1	1	1	1	1	0	0	1	0
20 550 to 20 650	0	0	1	1	1	1	1	0	0	1	1
20 650 to 20 750	0	0	1	1	1	1	1	0	0	0	1
20 750 to 20 850	0	0	1	1	1	0	1	0	0	0	1
20 850 to 20 950	0	0	1	1	1	0	1	0	0	1	1
20 950 to 21 050	0	0	1	1	1	0	1	0	0	1	0
21 050 to 21 150	0	0	1	1	1	0	1	0	1	1	0
21 150 to 21 250	0	0	1	1	1	0	1	0	1	0	0
21 250 to 21 350	0	0	1	1	1	0	1	1	1	0	0
21 350 to 21 450	0	0	1	1	1	0	1	1	1	1	0
21 450 to 21 550	0	0	1	1	1	0	1	1	0	1	0
21 550 to 21 650	0	0	1	1	1	0	1	1	0	1	1
21 650 to 21 750	0	0	1	1	1	0	1	1	0	0	1
21 750 to 21 850	0	0	1	1	1	0	0	1	0	0	1
21 850 to 21 950	0	0	1	1	1	0	0	1	0	1	1
21 950 to 22 050	0	0	1	1	1	0	0	1	0	1	0
22 050 to 22 150	0	0	1	1	1	0	0	1	1	1	0
22 150 to 22 250	0	0	1	1	1	0	0	1	1	0	0
22 250 to 22 350	0	0	1	1	1	0	0	0	1	0	0
22 350 to 22 450	0	0	1	1	1	0	0	0	1	1	0
22 450 to 22 550	0	0	1	1	1	0	0	0	0	1	0
22 550 to 22 650	0	0	1	1	1	0	0	0	0	1	1
22 650 to 22 750	0	0	1	1	1	0	0	0	0	0	1
22 750 to 22 850	0	0	1	0	1	0	0	0	0	0	1
22 850 to 22 950	0	0	1	0	1	0	0	0	0	1	1
22 950 to 23 050	0	0	1	0	1	0	0	0	0	1	0
23 050 to 23 150	0	0	1	0	1	0	0	0	1	1	0
23 150 to 23 250	0	0	1	0	1	0	0	0	1	0	0
23 250 to 23 350	0	0	1	0	1	0	0	1	1	0	0
23 350 to 23 450	0	0	1	0	1	0	0	1	1	1	0
23 450 to 23 550	0	0	1	0	1	0	0	1	0	1	0
23 550 to 23 650	0	0	1	0	1	0	0	1	0	1	1
23 650 to 23 750	0	0	1	0	1	0	0	1	0	0	1
23 750 to 23 850	0	0	1	0	1	0	1	1	0	0	1
23 850 to 23 950	0	0	1	0	1	0	1	1	0	1	1
23 950 to 24 050	0	0	1	0	1	0	1	1	0	1	0
24 050 to 24 150	0	0	1	0	1	0	1	1	1	1	0
24 150 to 24 250	0	0	1	0	1	0	1	1	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
24 250 to 24 350	0	0	1	0	1	0	1	0	1	0	0
24 350 to 24 450	0	0	1	0	1	0	1	0	1	1	0
24 450 to 24 550	0	0	1	0	1	0	1	0	0	1	0
24 550 to 24 650	0	0	1	0	1	0	1	0	0	1	1
24 650 to 24 750	0	0	1	0	1	0	1	0	0	0	1
24 750 to 24 850	0	0	1	0	1	1	1	0	0	0	1
24 850 to 24 950	0	0	1	0	1	1	1	0	0	1	1
24 950 to 25 050	0	0	1	0	1	1	1	0	0	1	0
25 050 to 25 150	0	0	1	0	1	1	1	0	1	1	0
25 150 to 25 250	0	0	1	0	1	1	1	0	1	0	0
25 250 to 25 350	0	0	1	0	1	1	1	1	1	0	0
25 350 to 25 450	0	0	1	0	1	1	1	1	1	1	0
25 450 to 25 550	0	0	1	0	1	1	1	1	0	1	0
25 550 to 25 650	0	0	1	0	1	1	1	1	0	1	1
25 650 to 25 750	0	0	1	0	1	1	1	1	0	0	1
25 750 to 25 850	0	0	1	0	1	1	0	1	0	0	1
25 850 to 25 950	0	0	1	0	1	1	0	1	0	1	1
25 950 to 26 050	0	0	1	0	1	1	0	1	0	1	0
26 050 to 26 150	0	0	1	0	1	1	0	1	1	1	0
26 150 to 26 250	0	0	1	0	1	1	0	1	1	0	0
26 250 to 26 350	0	0	1	0	1	1	0	0	1	0	0
26 350 to 26 450	0	0	1	0	1	1	0	0	1	1	0
26 450 to 26 550	0	0	1	0	1	1	0	0	0	1	0
26 550 to 26 650	0	0	1	0	1	1	0	0	0	1	1
26 650 to 26 750	0	0	1	0	1	1	0	0	0	0	1
26 750 to 26 850	0	0	1	0	0	1	0	0	0	0	1
26 850 to 26 950	0	0	1	0	0	1	0	0	0	1	1
26 950 to 27 050	0	0	1	0	0	1	0	0	0	1	0
27 050 to 27 150	0	0	1	0	0	1	0	0	1	1	0
27 150 to 27 250	0	0	1	0	0	1	0	0	1	0	0
27 250 to 27 350	0	0	1	0	0	1	0	1	1	0	0
27 350 to 27 450	0	0	1	0	0	1	0	1	1	1	0
27 450 to 27 550	0	0	1	0	0	1	0	1	0	1	0
27 550 to 27 650	0	0	1	0	0	1	0	1	0	1	1
27 650 to 27 750	0	0	1	0	0	1	0	1	0	0	1
27 750 to 27 850	0	0	1	0	0	1	1	1	0	0	1
27 850 to 27 950	0	0	1	0	0	1	1	1	0	1	1
27 950 to 28 050	0	0	1	0	0	1	1	1	0	1	0
28 050 to 28 150	0	0	1	0	0	1	1	1	1	1	0
28 150 to 28 250	0	0	1	0	0	1	1	1	1	0	0
28 250 to 28 350	0	0	1	0	0	1	1	0	1	0	0
28 350 to 28 450	0	0	1	0	0	1	1	0	1	1	0
28 450 to 28 550	0	0	1	0	0	1	1	0	0	1	0
28 550 to 28 650	0	0	1	0	0	1	1	0	0	1	1
28 650 to 28 750	0	0	1	0	0	1	1	0	0	0	1
28 750 to 28 850	0	0	1	0	0	0	1	0	0	0	1
28 850 to 28 950	0	0	1	0	0	0	1	0	0	1	1
28 950 to 29 050	0	0	1	0	0	0	1	0	0	1	0
29 050 to 29 150	0	0	1	0	0	0	1	0	1	1	0
29 150 to 29 250	0	0	1	0	0	0	1	0	1	0	0
29 250 to 29 350	0	0	1	0	0	0	1	1	1	0	0
29 350 to 29 450	0	0	1	0	0	0	1	1	1	1	0
29 450 to 29 550	0	0	1	0	0	0	1	1	0	1	0
29 550 to 29 650	0	0	1	0	0	0	1	1	0	1	1
29 650 to 29 750	0	0	1	0	0	0	1	1	0	0	1
29 750 to 29 850	0	0	1	0	0	0	0	1	0	0	1
29 850 to 29 950	0	0	1	0	0	0	0	1	0	1	1
29 950 to 30 050	0	0	1	0	0	0	0	1	0	1	0
30 050 to 30 150	0	0	1	0	0	0	0	1	1	1	0
30 150 to 30 250	0	0	1	0	0	0	0	1	1	0	0
30 250 to 30 350	0	0	1	0	0	0	0	0	1	0	0
30 350 to 30 450	0	0	1	0	0	0	0	0	1	1	0
30 450 to 30 550	0	0	1	0	0	0	0	0	0	1	0
30 550 to 30 650	0	0	1	0	0	0	0	0	0	1	1
30 650 to 30 750	0	0	1	0	0	0	0	0	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
30 750 to 30 850	0	1	1	0	0	0	0	0	0	0	1
30 850 to 30 950	0	1	1	0	0	0	0	0	0	1	1
30 950 to 31 050	0	1	1	0	0	0	0	0	0	1	0
31 050 to 31 150	0	1	1	0	0	0	0	0	1	1	0
31 150 to 31 250	0	1	1	0	0	0	0	0	1	0	0
31 250 to 31 350	0	1	1	0	0	0	0	1	1	0	0
31 350 to 31 450	0	1	1	0	0	0	0	1	1	1	0
31 450 to 31 550	0	1	1	0	0	0	0	1	0	1	0
31 550 to 31 650	0	1	1	0	0	0	0	1	0	1	1
31 650 to 31 750	0	1	1	0	0	0	0	1	0	0	1
31 750 to 31 850	0	1	1	0	0	0	1	1	0	0	1
31 850 to 31 950	0	1	1	0	0	0	1	1	0	1	1
31 950 to 32 050	0	1	1	0	0	0	1	1	0	1	0
32 050 to 32 150	0	1	1	0	0	0	1	1	1	1	0
32 150 to 32 250	0	1	1	0	0	0	1	1	1	0	0
32 250 to 32 350	0	1	1	0	0	0	1	0	1	0	0
32 350 to 32 450	0	1	1	0	0	0	1	0	1	1	0
32 450 to 32 550	0	1	1	0	0	0	1	0	0	1	0
32 550 to 32 650	0	1	1	0	0	0	1	0	0	1	1
32 650 to 32 750	0	1	1	0	0	0	1	0	0	0	1
32 750 to 32 850	0	1	1	0	0	1	1	0	0	0	1
32 850 to 32 950	0	1	1	0	0	1	1	0	0	1	1
32 950 to 33 050	0	1	1	0	0	1	1	0	0	1	0
33 050 to 33 150	0	1	1	0	0	1	1	0	1	1	0
33 150 to 33 250	0	1	1	0	0	1	1	0	1	0	0
33 250 to 33 350	0	1	1	0	0	1	1	1	1	0	0
33 350 to 33 450	0	1	1	0	0	1	1	1	1	1	0
33 450 to 33 550	0	1	1	0	0	1	1	1	0	1	0
33 550 to 33 650	0	1	1	0	0	1	1	1	0	1	1
33 650 to 33 750	0	1	1	0	0	1	1	1	0	0	1
33 750 to 33 850	0	1	1	0	0	1	0	1	0	0	1
33 850 to 33 950	0	1	1	0	0	1	0	1	0	1	1
33 950 to 34 050	0	1	1	0	0	1	0	1	0	1	0
34 050 to 34 150	0	1	1	0	0	1	0	1	1	1	0
34 150 to 34 250	0	1	1	0	0	1	0	1	1	0	0
34 250 to 34 350	0	1	1	0	0	1	0	0	1	0	0
34 350 to 34 450	0	1	1	0	0	1	0	0	1	1	0
34 450 to 34 550	0	1	1	0	0	1	0	0	0	1	0
34 550 to 34 650	0	1	1	0	0	1	0	0	0	1	1
34 650 to 34 750	0	1	1	0	0	1	0	0	0	0	1
34 750 to 34 850	0	1	1	0	1	1	0	0	0	0	1
34 850 to 34 950	0	1	1	0	1	1	0	0	0	1	1
34 950 to 35 050	0	1	1	0	1	1	0	0	0	1	0
35 050 to 35 150	0	1	1	0	1	1	0	0	1	1	0
35 150 to 35 250	0	1	1	0	1	1	0	0	1	0	0
35 250 to 35 350	0	1	1	0	1	1	0	1	1	0	0
35 350 to 35 450	0	1	1	0	1	1	0	1	1	1	0
35 450 to 35 550	0	1	1	0	1	1	0	1	0	1	0
35 550 to 35 650	0	1	1	0	1	1	0	1	0	1	1
35 650 to 35 750	0	1	1	0	1	1	0	1	0	0	1
35 750 to 35 850	0	1	1	0	1	1	1	1	0	0	1
35 850 to 35 950	0	1	1	0	1	1	1	1	0	1	1
35 950 to 36 050	0	1	1	0	1	1	1	1	0	1	0
36 050 to 36 150	0	1	1	0	1	1	1	1	1	1	0
36 150 to 36 250	0	1	1	0	1	1	1	1	1	0	0
36 250 to 36 350	0	1	1	0	1	1	1	0	1	0	0
36 350 to 36 450	0	1	1	0	1	1	1	0	1	1	0
36 450 to 36 550	0	1	1	0	1	1	1	0	0	1	0
36 550 to 36 650	0	1	1	0	1	1	1	0	0	1	1
36 650 to 36 750	0	1	1	0	1	1	1	0	0	0	1
36 750 to 36 850	0	1	1	0	1	0	1	0	0	0	1
36 850 to 36 950	0	1	1	0	1	0	1	0	0	1	1
36 950 to 37 050	0	1	1	0	1	0	1	0	0	1	0
37 050 to 37 150	0	1	1	0	1	0	1	0	1	1	0
37 150 to 37 250	0	1	1	0	1	0	1	0	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
37 250 to 37 350	0	1	1	0	1	0	1	1	1	0	0
37 350 to 37 450	0	1	1	0	1	0	1	1	1	1	0
37 450 to 37 550	0	1	1	0	1	0	1	1	0	1	0
37 550 to 37 650	0	1	1	0	1	0	1	1	0	1	1
37 650 to 37 750	0	1	1	0	1	0	1	1	0	0	1
37 750 to 37 850	0	1	1	0	1	0	0	1	0	0	1
37 850 to 37 950	0	1	1	0	1	0	0	1	0	1	1
37 950 to 38 050	0	1	1	0	1	0	0	1	0	1	0
38 050 to 38 150	0	1	1	0	1	0	0	1	1	1	0
38 150 to 38 250	0	1	1	0	1	0	0	1	1	0	0
38 250 to 38 350	0	1	1	0	1	0	0	0	1	0	0
38 350 to 38 450	0	1	1	0	1	0	0	0	1	1	0
38 450 to 38 550	0	1	1	0	1	0	0	0	0	1	0
38 550 to 38 650	0	1	1	0	1	0	0	0	0	1	1
38 650 to 38 750	0	1	1	0	1	0	0	0	0	0	1
38 750 to 38 850	0	1	1	1	1	0	0	0	0	0	1
38 850 to 38 950	0	1	1	1	1	0	0	0	0	1	1
38 950 to 39 050	0	1	1	1	1	0	0	0	0	1	0
39 050 to 39 150	0	1	1	1	1	0	0	0	1	1	0
39 150 to 39 250	0	1	1	1	1	0	0	0	1	0	0
39 250 to 39 350	0	1	1	1	1	0	0	1	1	0	0
39 350 to 39 450	0	1	1	1	1	0	0	1	1	1	0
39 450 to 39 550	0	1	1	1	1	0	0	1	0	1	0
39 550 to 39 650	0	1	1	1	1	0	0	1	0	1	1
39 650 to 39 750	0	1	1	1	1	0	0	1	0	0	1
39 750 to 39 850	0	1	1	1	1	0	1	1	0	0	1
39 850 to 39 950	0	1	1	1	1	0	1	1	0	1	1
39 950 to 40 050	0	1	1	1	1	0	1	1	0	1	0
40 050 to 40 150	0	1	1	1	1	0	1	1	1	1	0
40 150 to 40 250	0	1	1	1	1	0	1	1	1	0	0
40 250 to 40 350	0	1	1	1	1	0	1	0	1	0	0
40 350 to 40 450	0	1	1	1	1	0	1	0	1	1	0
40 450 to 40 550	0	1	1	1	1	0	1	0	0	1	0
40 550 to 40 650	0	1	1	1	1	0	1	0	0	1	1
40 650 to 40 750	0	1	1	1	1	0	1	0	0	0	1
40 750 to 40 850	0	1	1	1	1	1	1	0	0	0	1
40 850 to 40 950	0	1	1	1	1	1	1	0	0	1	1
40 950 to 41 050	0	1	1	1	1	1	1	0	0	1	0
41 050 to 41 150	0	1	1	1	1	1	1	0	1	1	0
41 150 to 41 250	0	1	1	1	1	1	1	0	1	0	0
41 250 to 41 350	0	1	1	1	1	1	1	1	1	0	0
41 350 to 41 450	0	1	1	1	1	1	1	1	1	1	0
41 450 to 41 550	0	1	1	1	1	1	1	1	0	1	0
41 550 to 41 650	0	1	1	1	1	1	1	1	0	1	1
41 650 to 41 750	0	1	1	1	1	1	1	1	0	0	1
41 750 to 41 850	0	1	1	1	1	1	0	1	0	0	1
41 850 to 41 950	0	1	1	1	1	1	0	1	0	1	1
41 950 to 42 050	0	1	1	1	1	1	0	1	0	1	0
42 050 to 42 150	0	1	1	1	1	1	0	1	1	1	0
42 150 to 42 250	0	1	1	1	1	1	0	1	1	0	0
42 250 to 42 350	0	1	1	1	1	1	0	0	1	0	0
42 350 to 42 450	0	1	1	1	1	1	0	0	1	1	0
42 450 to 42 550	0	1	1	1	1	1	0	0	0	1	0
42 550 to 42 650	0	1	1	1	1	1	0	0	0	1	1
42 650 to 42 750	0	1	1	1	1	1	0	0	0	0	1
42 750 to 42 850	0	1	1	1	0	1	0	0	0	0	1
42 850 to 42 950	0	1	1	1	0	1	0	0	0	1	1
42 950 to 43 050	0	1	1	1	0	1	0	0	0	1	0
43 050 to 43 150	0	1	1	1	0	1	0	0	1	1	0
43 150 to 43 250	0	1	1	1	0	1	0	0	1	0	0
43 250 to 43 350	0	1	1	1	0	1	0	1	1	0	0
43 350 to 43 450	0	1	1	1	0	1	0	1	1	1	0
43 450 to 43 550	0	1	1	1	0	1	0	1	0	1	0
43 550 to 43 650	0	1	1	1	0	1	0	1	0	1	1
43 650 to 43 750	0	1	1	1	0	1	0	1	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
43 750 to 43 850	0	1	1	1	0	1	1	1	0	0	1
43 850 to 43 950	0	1	1	1	0	1	1	1	0	1	1
43 950 to 44 050	0	1	1	1	0	1	1	1	0	1	0
44 050 to 44 150	0	1	1	1	0	1	1	1	1	1	0
44 150 to 44 250	0	1	1	1	0	1	1	1	1	0	0
44 250 to 44 350	0	1	1	1	0	1	1	0	1	0	0
44 350 to 44 450	0	1	1	1	0	1	1	0	1	1	0
44 450 to 44 550	0	1	1	1	0	1	1	0	0	1	0
44 550 to 44 650	0	1	1	1	0	1	1	0	0	1	1
44 650 to 44 750	0	1	1	1	0	1	1	0	0	0	1
44 750 to 44 850	0	1	1	1	0	0	1	0	0	0	1
44 850 to 44 950	0	1	1	1	0	0	1	0	0	1	1
44 950 to 45 050	0	1	1	1	0	0	1	0	0	1	0
45 050 to 45 150	0	1	1	1	0	0	1	0	1	1	0
45 150 to 45 250	0	1	1	1	0	0	1	0	1	0	0
45 250 to 45 350	0	1	1	1	0	0	1	1	1	0	0
45 350 to 45 450	0	1	1	1	0	0	1	1	1	1	0
45 450 to 45 550	0	1	1	1	0	0	1	1	0	1	0
45 550 to 45 650	0	1	1	1	0	0	1	1	0	1	1
45 650 to 45 750	0	1	1	1	0	0	1	1	0	0	1
45 750 to 45 850	0	1	1	1	0	0	0	1	0	0	1
45 850 to 45 950	0	1	1	1	0	0	0	1	0	1	1
45 950 to 46 050	0	1	1	1	0	0	0	1	0	1	0
46 050 to 46 150	0	1	1	1	0	0	0	1	1	1	0
46 150 to 46 250	0	1	1	1	0	0	0	1	1	0	0
46 250 to 46 350	0	1	1	1	0	0	0	0	1	0	0
46 350 to 46 450	0	1	1	1	0	0	0	0	1	1	0
46 450 to 46 550	0	1	1	1	0	0	0	0	0	1	0
46 550 to 46 650	0	1	1	1	0	0	0	0	0	1	1
46 650 to 46 750	0	1	1	1	0	0	0	0	0	0	1
46 750 to 46 850	0	1	0	1	0	0	0	0	0	0	1
46 850 to 46 950	0	1	0	1	0	0	0	0	0	1	1
46 950 to 47 050	0	1	0	1	0	0	0	0	0	1	0
47 050 to 47 150	0	1	0	1	0	0	0	0	1	1	0
47 150 to 47 250	0	1	0	1	0	0	0	0	1	0	0
47 250 to 47 350	0	1	0	1	0	0	0	1	1	0	0
47 350 to 47 450	0	1	0	1	0	0	0	1	1	1	0
47 450 to 47 550	0	1	0	1	0	0	0	1	0	1	0
47 550 to 47 650	0	1	0	1	0	0	0	1	0	1	1
47 650 to 47 750	0	1	0	1	0	0	0	1	0	0	1
47 750 to 47 850	0	1	0	1	0	0	1	1	0	0	1
47 850 to 47 950	0	1	0	1	0	0	1	1	0	1	1
47 950 to 48 050	0	1	0	1	0	0	1	1	0	1	0
48 050 to 48 150	0	1	0	1	0	0	1	1	1	1	0
48 150 to 48 250	0	1	0	1	0	0	1	1	1	0	0
48 250 to 48 350	0	1	0	1	0	0	1	0	1	0	0
48 350 to 48 450	0	1	0	1	0	0	1	0	1	1	0
48 450 to 48 550	0	1	0	1	0	0	1	0	0	1	0
48 550 to 48 650	0	1	0	1	0	0	1	0	0	1	1
48 650 to 48 750	0	1	0	1	0	0	1	0	0	0	1
48 750 to 48 850	0	1	0	1	0	1	1	0	0	0	1
48 850 to 48 950	0	1	0	1	0	1	1	0	0	1	1
48 950 to 49 050	0	1	0	1	0	1	1	0	0	1	0
49 050 to 49 150	0	1	0	1	0	1	1	0	1	1	0
49 150 to 49 250	0	1	0	1	0	1	1	0	1	0	0
49 250 to 49 350	0	1	0	1	0	1	1	1	1	0	0
49 350 to 49 450	0	1	0	1	0	1	1	1	1	1	0
49 450 to 49 550	0	1	0	1	0	1	1	1	0	1	0
49 550 to 49 650	0	1	0	1	0	1	1	1	0	1	1
49 650 to 49 750	0	1	0	1	0	1	1	1	0	0	1
49 750 to 49 850	0	1	0	1	0	1	0	1	0	0	1
49 850 to 49 950	0	1	0	1	0	1	0	1	0	1	1
49 950 to 50 050	0	1	0	1	0	1	0	1	0	1	0
50 050 to 50 150	0	1	0	1	0	1	0	1	1	1	0
50 150 to 50 250	0	1	0	1	0	1	0	1	1	0	0

Table B (cont.)

RANGE			PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
50 250	to	50 350	0	1	0	1	0	1	0	0	1	0	0
50 350	to	50 450	0	1	0	1	0	1	0	0	1	1	0
50 450	to	50 550	0	1	0	1	0	1	0	0	0	1	0
50 550	to	50 650	0	1	0	1	0	1	0	0	0	1	1
50 650	to	50 750	0	1	0	1	0	1	0	0	0	0	1
50 750	to	50 850	0	1	0	1	1	1	0	0	0	0	1
50 850	to	50 950	0	1	0	1	1	1	0	0	0	1	1
50 950	to	51 050	0	1	0	1	1	1	0	0	0	1	0
51 050	to	51 150	0	1	0	1	1	1	0	0	1	1	0
51 150	to	51 250	0	1	0	1	1	1	0	0	1	0	0
51 250	to	51 350	0	1	0	1	1	1	0	1	1	0	0
51 350	to	51 450	0	1	0	1	1	1	0	1	1	1	0
51 450	to	51 550	0	1	0	1	1	1	0	1	0	1	0
51 550	to	51 650	0	1	0	1	1	1	0	1	0	1	1
51 650	to	51 750	0	1	0	1	1	1	0	1	0	0	1
51 750	to	51 850	0	1	0	1	1	1	1	1	0	0	1
51 850	to	51 950	0	1	0	1	1	1	1	1	0	1	1
51 950	to	52 050	0	1	0	1	1	1	1	1	0	1	0
52 050	to	52 150	0	1	0	1	1	1	1	1	1	1	0
52 150	to	52 250	0	1	0	1	1	1	1	1	1	0	0
52 250	to	52 350	0	1	0	1	1	1	1	0	1	0	0
52 350	to	52 450	0	1	0	1	1	1	1	0	1	1	0
52 450	to	52 550	0	1	0	1	1	1	1	0	0	1	0
52 550	to	52 650	0	1	0	1	1	1	1	0	0	1	1
52 650	to	52 750	0	1	0	1	1	1	1	0	0	0	1
52 750	to	52 850	0	1	0	1	1	0	1	0	0	0	1
52 850	to	52 950	0	1	0	1	1	0	1	0	0	1	1
52 950	to	53 050	0	1	0	1	1	0	1	0	0	1	0
53 050	to	53 150	0	1	0	1	1	0	1	0	1	1	0
53 150	to	53 250	0	1	0	1	1	0	1	0	1	0	0
53 250	to	53 350	0	1	0	1	1	0	1	1	1	0	0
53 350	to	53 450	0	1	0	1	1	0	1	1	1	1	0
53 450	to	53 550	0	1	0	1	1	0	1	1	0	1	0
53 550	to	53 650	0	1	0	1	1	0	1	1	0	1	1
53 650	to	53 750	0	1	0	1	1	0	1	1	0	0	1
53 750	to	53 850	0	1	0	1	1	0	0	1	0	0	1
53 850	to	53 950	0	1	0	1	1	0	0	1	0	1	1
53 950	to	54 050	0	1	0	1	1	0	0	1	0	1	0
54 050	to	54 150	0	1	0	1	1	0	0	1	1	1	0
54 150	to	54 250	0	1	0	1	1	0	0	1	1	0	0
54 250	to	54 350	0	1	0	1	1	0	0	0	1	0	0
54 350	to	54 450	0	1	0	1	1	0	0	0	1	1	0
54 450	to	54 550	0	1	0	1	1	0	0	0	0	1	0
54 550	to	54 650	0	1	0	1	1	0	0	0	0	1	1
54 650	to	54 750	0	1	0	1	1	0	0	0	0	0	1
54 750	to	54 850	0	1	0	0	1	0	0	0	0	0	1
54 850	to	54 950	0	1	0	0	1	0	0	0	0	1	1
54 950	to	55 050	0	1	0	0	1	0	0	0	0	1	0
55 050	to	55 150	0	1	0	0	1	0	0	0	1	1	0
55 150	to	55 250	0	1	0	0	1	0	0	0	1	0	0
55 250	to	55 350	0	1	0	0	1	0	0	1	1	0	0
55 350	to	55 450	0	1	0	0	1	0	0	1	1	1	0
55 450	to	55 550	0	1	0	0	1	0	0	1	0	1	0
55 550	to	55 650	0	1	0	0	1	0	0	1	0	1	1
55 650	to	55 750	0	1	0	0	1	0	0	1	0	0	1
55 750	to	55 850	0	1	0	0	1	0	1	1	0	0	1
55 850	to	55 950	0	1	0	0	1	0	1	1	0	1	1
55 950	to	56 050	0	1	0	0	1	0	1	1	0	1	0
56 050	to	56 150	0	1	0	0	1	0	1	1	1	1	0
56 150	to	56 250	0	1	0	0	1	0	1	1	1	0	0
56 250	to	56 350	0	1	0	0	1	0	1	0	1	0	0
56 350	to	56 450	0	1	0	0	1	0	1	0	1	1	0
56 450	to	56 550	0	1	0	0	1	0	1	0	0	1	0
56 550	to	56 650	0	1	0	0	1	0	1	0	0	1	1
56 650	to	56 750	0	1	0	0	1	0	1	0	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
56 750 to 56 850	0	1	0	0	1	1	1	0	0	0	1
56 850 to 56 950	0	1	0	0	1	1	1	0	0	1	1
56 950 to 57 050	0	1	0	0	1	1	1	0	0	1	0
57 050 to 57 150	0	1	0	0	1	1	1	0	1	1	0
57 150 to 57 250	0	1	0	0	1	1	1	0	1	0	0
57 250 to 57 350	0	1	0	0	1	1	1	1	1	0	0
57 350 to 57 450	0	1	0	0	1	1	1	1	1	1	0
57 450 to 57 550	0	1	0	0	1	1	1	1	0	1	0
57 550 to 57 650	0	1	0	0	1	1	1	1	0	1	1
57 650 to 57 750	0	1	0	0	1	1	1	1	0	0	1
57 750 to 57 850	0	1	0	0	1	1	0	1	0	0	1
57 850 to 57 950	0	1	0	0	1	1	0	1	0	1	1
57 950 to 58 050	0	1	0	0	1	1	0	1	0	1	0
58 050 to 58 150	0	1	0	0	1	1	0	1	1	1	0
58 150 to 58 250	0	1	0	0	1	1	0	1	1	0	0
58 250 to 58 350	0	1	0	0	1	1	0	0	1	0	0
58 350 to 58 450	0	1	0	0	1	1	0	0	1	1	0
58 450 to 58 550	0	1	0	0	1	1	0	0	0	1	0
58 550 to 58 650	0	1	0	0	1	1	0	0	0	1	1
58 650 to 58 750	0	1	0	0	1	1	0	0	0	0	1
58 750 to 58 850	0	1	0	0	0	1	0	0	0	0	1
58 850 to 58 950	0	1	0	0	0	1	0	0	0	1	1
58 950 to 59 050	0	1	0	0	0	1	0	0	0	1	0
59 050 to 59 150	0	1	0	0	0	1	0	0	1	1	0
59 150 to 59 250	0	1	0	0	0	1	0	0	1	0	0
59 250 to 59 350	0	1	0	0	0	1	0	1	1	0	0
59 350 to 59 450	0	1	0	0	0	1	0	1	1	1	0
59 450 to 59 550	0	1	0	0	0	1	0	1	0	1	0
59 550 to 59 650	0	1	0	0	0	1	0	1	0	1	1
59 650 to 59 750	0	1	0	0	0	1	0	1	0	0	1
59 750 to 59 850	0	1	0	0	0	1	1	1	0	0	1
59 850 to 59 950	0	1	0	0	0	1	1	1	0	1	1
59 950 to 60 050	0	1	0	0	0	1	1	1	0	1	0
60 050 to 60 150	0	1	0	0	0	1	1	1	1	1	0
60 150 to 60 250	0	1	0	0	0	1	1	1	1	0	0
60 250 to 60 350	0	1	0	0	0	1	1	0	1	0	0
60 350 to 60 450	0	1	0	0	0	1	1	0	1	1	0
60 450 to 60 550	0	1	0	0	0	1	1	0	0	1	0
60 550 to 60 650	0	1	0	0	0	1	1	0	0	1	1
60 650 to 60 750	0	1	0	0	0	1	1	0	0	0	1
60 750 to 60 850	0	1	0	0	0	0	1	0	0	0	1
60 850 to 60 950	0	1	0	0	0	0	1	0	0	1	1
60 950 to 61 050	0	1	0	0	0	0	1	0	0	1	0
61 050 to 61 150	0	1	0	0	0	0	1	0	1	1	0
61 150 to 61 250	0	1	0	0	0	0	1	0	1	0	0
61 250 to 61 350	0	1	0	0	0	0	1	1	1	0	0
61 350 to 61 450	0	1	0	0	0	0	1	1	1	1	0
61 450 to 61 550	0	1	0	0	0	0	1	1	0	1	0
61 550 to 61 650	0	1	0	0	0	0	1	1	0	1	1
61 650 to 61 750	0	1	0	0	0	0	1	1	0	0	1
61 750 to 61 850	0	1	0	0	0	0	0	1	0	0	1
61 850 to 61 950	0	1	0	0	0	0	0	1	0	1	1
61 950 to 62 050	0	1	0	0	0	0	0	1	0	1	0
62 050 to 62 150	0	1	0	0	0	0	0	1	1	1	0
62 150 to 62 250	0	1	0	0	0	0	0	1	1	0	0
62 250 to 62 350	0	1	0	0	0	0	0	0	1	0	0
62 350 to 62 450	0	1	0	0	0	0	0	0	1	1	0
62 450 to 62 550	0	1	0	0	0	0	0	0	0	1	0
62 550 to 62 650	0	1	0	0	0	0	0	0	0	1	1
62 650 to 62 750	0	1	0	0	0	0	0	0	0	0	1
62 750 to 62 850	1	1	0	0	0	0	0	0	0	0	1
62 850 to 62 950	1	1	0	0	0	0	0	0	0	1	1
62 950 to 63 050	1	1	0	0	0	0	0	0	0	1	0
63 050 to 63 150	1	1	0	0	0	0	0	0	1	1	0
63 150 to 63 250	1	1	0	0	0	0	0	0	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
63 250 to 63 350	1	1	0	0	0	0	0	1	1	0	0
63 350 to 63 450	1	1	0	0	0	0	0	1	1	1	0
63 450 to 63 550	1	1	0	0	0	0	0	1	0	1	0
63 550 to 63 650	1	1	0	0	0	0	0	1	0	1	1
63 650 to 63 750	1	1	0	0	0	0	0	1	0	0	1
63 750 to 63 850	1	1	0	0	0	0	1	1	0	0	1
63 850 to 63 950	1	1	0	0	0	0	1	1	0	1	1
63 950 to 64 050	1	1	0	0	0	0	1	1	0	1	0
64 050 to 64 150	1	1	0	0	0	0	1	1	1	1	0
64 150 to 64 250	1	1	0	0	0	0	1	1	1	0	0
64 250 to 64 350	1	1	0	0	0	0	1	0	1	0	0
64 350 to 64 450	1	1	0	0	0	0	1	0	1	1	0
64 450 to 64 550	1	1	0	0	0	0	1	0	0	1	0
64 550 to 64 650	1	1	0	0	0	0	1	0	0	1	1
64 650 to 64 750	1	1	0	0	0	0	1	0	0	0	1
64 750 to 64 850	1	1	0	0	0	1	1	0	0	0	1
64 850 to 64 950	1	1	0	0	0	1	1	0	0	1	1
64 950 to 65 050	1	1	0	0	0	1	1	0	0	1	0
65 050 to 65 150	1	1	0	0	0	1	1	0	1	1	0
65 150 to 65 250	1	1	0	0	0	1	1	0	1	0	0
65 250 to 65 350	1	1	0	0	0	1	1	1	1	0	0
65 350 to 65 450	1	1	0	0	0	1	1	1	1	1	0
65 450 to 65 550	1	1	0	0	0	1	1	1	0	1	0
65 550 to 65 650	1	1	0	0	0	1	1	1	0	1	1
65 650 to 65 750	1	1	0	0	0	1	1	1	0	0	1
65 750 to 65 850	1	1	0	0	0	1	0	1	0	0	1
65 850 to 65 950	1	1	0	0	0	1	0	1	0	1	1
65 950 to 66 050	1	1	0	0	0	1	0	1	0	1	0
66 050 to 66 150	1	1	0	0	0	1	0	1	1	1	0
66 150 to 66 250	1	1	0	0	0	1	0	1	1	0	0
66 250 to 66 350	1	1	0	0	0	1	0	0	1	0	0
66 350 to 66 450	1	1	0	0	0	1	0	0	1	1	0
66 450 to 66 550	1	1	0	0	0	1	0	0	0	1	0
66 550 to 66 650	1	1	0	0	0	1	0	0	0	1	1
66 650 to 66 750	1	1	0	0	0	1	0	0	0	0	1
66 750 to 66 850	1	1	0	0	1	1	0	0	0	0	1
66 850 to 66 950	1	1	0	0	1	1	0	0	0	1	1
66 950 to 67 050	1	1	0	0	1	1	0	0	0	1	0
67 050 to 67 150	1	1	0	0	1	1	0	0	1	1	0
67 150 to 67 250	1	1	0	0	1	1	0	0	1	0	0
67 250 to 67 350	1	1	0	0	1	1	0	1	1	0	0
67 350 to 67 450	1	1	0	0	1	1	0	1	1	1	0
67 450 to 67 550	1	1	0	0	1	1	0	1	0	1	0
67 550 to 67 650	1	1	0	0	1	1	0	1	0	1	1
67 650 to 67 750	1	1	0	0	1	1	0	1	0	0	1
67 750 to 67 850	1	1	0	0	1	1	1	1	0	0	1
67 850 to 67 950	1	1	0	0	1	1	1	1	0	1	1
67 950 to 68 050	1	1	0	0	1	1	1	1	0	1	0
68 050 to 68 150	1	1	0	0	1	1	1	1	1	1	0
68 150 to 68 250	1	1	0	0	1	1	1	1	1	0	0
68 250 to 68 350	1	1	0	0	1	1	1	0	1	0	0
68 350 to 68 450	1	1	0	0	1	1	1	0	1	1	0
68 450 to 68 550	1	1	0	0	1	1	1	0	0	1	0
68 550 to 68 650	1	1	0	0	1	1	1	0	0	1	1
68 650 to 68 750	1	1	0	0	1	1	1	0	0	0	1
68 750 to 68 850	1	1	0	0	1	0	1	0	0	0	1
68 850 to 68 950	1	1	0	0	1	0	1	0	0	1	1
68 950 to 69 050	1	1	0	0	1	0	1	0	0	1	0
69 050 to 69 150	1	1	0	0	1	0	1	0	1	1	0
69 150 to 69 250	1	1	0	0	1	0	1	0	1	0	0
69 250 to 69 350	1	1	0	0	1	0	1	1	1	0	0
69 350 to 69 450	1	1	0	0	1	0	1	1	1	1	0
69 450 to 69 550	1	1	0	0	1	0	1	1	0	1	0
69 550 to 69 650	1	1	0	0	1	0	1	1	0	1	1
69 650 to 69 750	1	1	0	0	1	0	1	1	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
69 750 to 69 850	1	1	0	0	1	0	0	1	0	0	1
69 850 to 69 950	1	1	0	0	1	0	0	1	0	1	1
69 950 to 70 050	1	1	0	0	1	0	0	1	0	1	0
70 050 to 70 150	1	1	0	0	1	0	0	1	1	1	0
70 150 to 70 250	1	1	0	0	1	0	0	1	1	0	0
70 250 to 70 350	1	1	0	0	1	0	0	0	1	0	0
70 350 to 70 450	1	1	0	0	1	0	0	0	1	1	0
70 450 to 70 550	1	1	0	0	1	0	0	0	0	1	0
70 550 to 70 650	1	1	0	0	1	0	0	0	0	1	1
70 650 to 70 750	1	1	0	0	1	0	0	0	0	0	1
70 750 to 70 850	1	1	0	1	1	0	0	0	0	0	1
70 850 to 70 950	1	1	0	1	1	0	0	0	0	1	1
70 950 to 71 050	1	1	0	1	1	0	0	0	0	1	0
71 050 to 71 150	1	1	0	1	1	0	0	0	1	1	0
71 150 to 71 250	1	1	0	1	1	0	0	0	1	0	0
71 250 to 71 350	1	1	0	1	1	0	0	1	1	0	0
71 350 to 71 450	1	1	0	1	1	0	0	1	1	1	0
71 450 to 71 550	1	1	0	1	1	0	0	1	0	1	0
71 550 to 71 650	1	1	0	1	1	0	0	1	0	1	1
71 650 to 71 750	1	1	0	1	1	0	0	1	0	0	1
71 750 to 71 850	1	1	0	1	1	0	1	1	0	0	1
71 850 to 71 950	1	1	0	1	1	0	1	1	0	1	1
71 950 to 72 050	1	1	0	1	1	0	1	1	0	1	0
72 050 to 72 150	1	1	0	1	1	0	1	1	1	1	0
72 150 to 72 250	1	1	0	1	1	0	1	1	1	0	0
72 250 to 72 350	1	1	0	1	1	0	1	0	1	0	0
72 350 to 72 450	1	1	0	1	1	0	1	0	1	1	0
72 450 to 72 550	1	1	0	1	1	0	1	0	0	1	0
72 550 to 72 650	1	1	0	1	1	0	1	0	0	1	1
72 650 to 72 750	1	1	0	1	1	0	1	0	0	0	1
72 750 to 72 850	1	1	0	1	1	1	1	0	0	0	1
72 850 to 72 950	1	1	0	1	1	1	1	0	0	1	1
72 950 to 73 050	1	1	0	1	1	1	1	0	0	1	0
73 050 to 73 150	1	1	0	1	1	1	1	0	1	1	0
73 150 to 73 250	1	1	0	1	1	1	1	0	1	0	0
73 250 to 73 350	1	1	0	1	1	1	1	1	1	0	0
73 350 to 73 450	1	1	0	1	1	1	1	1	1	1	0
73 450 to 73 550	1	1	0	1	1	1	1	1	0	1	0
73 550 to 73 650	1	1	0	1	1	1	1	1	0	1	1
73 650 to 73 750	1	1	0	1	1	1	1	1	0	0	1
73 750 to 73 850	1	1	0	1	1	1	0	1	0	0	1
73 850 to 73 950	1	1	0	1	1	1	0	1	0	1	1
73 950 to 74 050	1	1	0	1	1	1	0	1	0	1	0
74 050 to 74 150	1	1	0	1	1	1	0	1	1	1	0
74 150 to 74 250	1	1	0	1	1	1	0	1	1	0	0
74 250 to 74 350	1	1	0	1	1	1	0	0	1	0	0
74 350 to 74 450	1	1	0	1	1	1	0	0	1	1	0
74 450 to 74 550	1	1	0	1	1	1	0	0	0	1	0
74 550 to 74 650	1	1	0	1	1	1	0	0	0	1	1
74 650 to 74 750	1	1	0	1	1	1	0	0	0	0	1
74 750 to 74 850	1	1	0	1	0	1	0	0	0	0	1
74 850 to 74 950	1	1	0	1	0	1	0	0	0	1	1
74 950 to 75 050	1	1	0	1	0	1	0	0	0	1	0
75 050 to 75 150	1	1	0	1	0	1	0	0	1	1	0
75 150 to 75 250	1	1	0	1	0	1	0	0	1	0	0
75 250 to 75 350	1	1	0	1	0	1	0	1	1	0	0
75 350 to 75 450	1	1	0	1	0	1	0	1	1	1	0
75 450 to 75 550	1	1	0	1	0	1	0	1	0	1	0
75 550 to 75 650	1	1	0	1	0	1	0	1	0	1	1
75 650 to 75 750	1	1	0	1	0	1	0	1	0	0	1
75 750 to 75 850	1	1	0	1	0	1	1	1	0	0	1
75 850 to 75 950	1	1	0	1	0	1	1	1	0	1	1
75 950 to 76 050	1	1	0	1	0	1	1	1	0	1	0
76 050 to 76 150	1	1	0	1	0	1	1	1	1	1	0
76 150 to 76 250	1	1	0	1	0	1	1	1	1	0	0

Table B (cont.)

RANGE			PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
76 250	to	76 350	1	1	0	1	0	1	1	0	1	0	0
76 350	to	76 450	1	1	0	1	0	1	1	0	1	1	0
76 450	to	76 550	1	1	0	1	0	1	1	0	0	1	0
76 550	to	76 650	1	1	0	1	0	1	1	0	0	1	1
76 650	to	76 750	1	1	0	1	0	1	1	0	0	0	1
76 750	to	76 850	1	1	0	1	0	0	1	0	0	0	1
76 850	to	76 950	1	1	0	1	0	0	1	0	0	1	1
76 950	to	77 050	1	1	0	1	0	0	1	0	0	1	0
77 050	to	77 150	1	1	0	1	0	0	1	0	1	1	0
77 150	to	77 250	1	1	0	1	0	0	1	0	1	0	0
77 250	to	77 350	1	1	0	1	0	0	1	1	1	0	0
77 350	to	77 450	1	1	0	1	0	0	1	1	1	1	0
77 450	to	77 550	1	1	0	1	0	0	1	1	0	1	0
77 550	to	77 650	1	1	0	1	0	0	1	1	0	1	1
77 650	to	77 750	1	1	0	1	0	0	1	1	0	0	1
77 750	to	77 850	1	1	0	1	0	0	0	1	0	0	1
77 850	to	77 950	1	1	0	1	0	0	0	1	0	1	1
77 950	to	78 050	1	1	0	1	0	0	0	1	0	1	0
78 050	to	78 150	1	1	0	1	0	0	0	1	1	1	0
78 150	to	78 250	1	1	0	1	0	0	0	1	1	0	0
78 250	to	78 350	1	1	0	1	0	0	0	0	1	0	0
78 350	to	78 450	1	1	0	1	0	0	0	0	1	1	0
78 450	to	78 550	1	1	0	1	0	0	0	0	0	1	0
78 550	to	78 650	1	1	0	1	0	0	0	0	0	1	1
78 650	to	78 750	1	1	0	1	0	0	0	0	0	0	1
78 750	to	78 850	1	1	1	1	0	0	0	0	0	0	1
78 850	to	78 950	1	1	1	1	0	0	0	0	0	1	1
78 950	to	79 050	1	1	1	1	0	0	0	0	0	1	0
79 050	to	79 150	1	1	1	1	0	0	0	0	1	1	0
79 150	to	79 250	1	1	1	1	0	0	0	0	1	0	0
79 250	to	79 350	1	1	1	1	0	0	0	1	1	0	0
79 350	to	79 450	1	1	1	1	0	0	0	1	1	1	0
79 450	to	79 550	1	1	1	1	0	0	0	1	0	1	0
79 550	to	79 650	1	1	1	1	0	0	0	1	0	1	1
79 650	to	79 750	1	1	1	1	0	0	0	1	0	0	1
79 750	to	79 850	1	1	1	1	0	0	1	1	0	0	1
79 850	to	79 950	1	1	1	1	0	0	1	1	0	1	1
79 950	to	80 050	1	1	1	1	0	0	1	1	0	1	0
80 050	to	80 150	1	1	1	1	0	0	1	1	1	1	0
80 150	to	80 250	1	1	1	1	0	0	1	1	1	0	0
80 250	to	80 350	1	1	1	1	0	0	1	0	1	0	0
80 350	to	80 450	1	1	1	1	0	0	1	0	1	1	0
80 450	to	80 550	1	1	1	1	0	0	1	0	0	1	0
80 550	to	80 650	1	1	1	1	0	0	1	0	0	1	1
80 650	to	80 750	1	1	1	1	0	0	1	0	0	0	1
80 750	to	80 850	1	1	1	1	0	1	1	0	0	0	1
80 850	to	80 950	1	1	1	1	0	1	1	0	0	1	1
80 950	to	81 050	1	1	1	1	0	1	1	0	0	1	0
81 050	to	81 150	1	1	1	1	0	1	1	0	1	1	0
81 150	to	81 250	1	1	1	1	0	1	1	0	1	0	0
81 250	to	81 350	1	1	1	1	0	1	1	1	1	0	0
81 350	to	81 450	1	1	1	1	0	1	1	1	1	1	0
81 450	to	81 550	1	1	1	1	0	1	1	1	0	1	0
81 550	to	81 650	1	1	1	1	0	1	1	1	0	1	1
81 650	to	81 750	1	1	1	1	0	1	1	1	0	0	1
81 750	to	81 850	1	1	1	1	0	1	0	1	0	0	1
81 850	to	81 950	1	1	1	1	0	1	0	1	0	1	1
81 950	to	82 050	1	1	1	1	0	1	0	1	0	1	0
82 050	to	82 150	1	1	1	1	0	1	0	1	1	1	0
82 150	to	82 250	1	1	1	1	0	1	0	1	1	0	0
82 250	to	82 350	1	1	1	1	0	1	0	0	1	0	0
82 350	to	82 450	1	1	1	1	0	1	0	0	1	1	0
82 450	to	82 550	1	1	1	1	0	1	0	0	0	1	0
82 550	to	82 650	1	1	1	1	0	1	0	0	0	1	1
82 650	to	82 750	1	1	1	1	0	1	0	0	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
82 750 to 82 850	1	1	1	1	1	1	0	0	0	0	1
82 850 to 82 950	1	1	1	1	1	1	0	0	0	1	1
82 950 to 83 050	1	1	1	1	1	1	0	0	0	1	0
83 050 to 83 150	1	1	1	1	1	1	0	0	1	1	0
83 150 to 83 250	1	1	1	1	1	1	0	0	1	0	0
83 250 to 83 350	1	1	1	1	1	1	0	1	1	0	0
83 350 to 83 450	1	1	1	1	1	1	0	1	1	1	0
83 450 to 83 550	1	1	1	1	1	1	0	1	0	1	0
83 550 to 83 650	1	1	1	1	1	1	0	1	0	1	1
83 650 to 83 750	1	1	1	1	1	1	0	1	0	0	1
83 750 to 83 850	1	1	1	1	1	1	1	1	0	0	1
83 850 to 83 950	1	1	1	1	1	1	1	1	0	1	1
83 950 to 84 050	1	1	1	1	1	1	1	1	0	1	0
84 050 to 84 150	1	1	1	1	1	1	1	1	1	1	0
84 150 to 84 250	1	1	1	1	1	1	1	1	1	0	0
84 250 to 84 350	1	1	1	1	1	1	1	0	1	0	0
84 350 to 84 450	1	1	1	1	1	1	1	0	1	1	0
84 450 to 84 550	1	1	1	1	1	1	1	0	0	1	0
84 550 to 84 650	1	1	1	1	1	1	1	0	0	1	1
84 650 to 84 750	1	1	1	1	1	1	1	0	0	0	1
84 750 to 84 850	1	1	1	1	1	0	1	0	0	0	1
84 850 to 84 950	1	1	1	1	1	0	1	0	0	1	1
84 950 to 85 050	1	1	1	1	1	0	1	0	0	1	0
85 050 to 85 150	1	1	1	1	1	0	1	0	1	1	0
85 150 to 85 250	1	1	1	1	1	0	1	0	1	0	0
85 250 to 85 350	1	1	1	1	1	0	1	1	1	0	0
85 350 to 85 450	1	1	1	1	1	0	1	1	1	1	0
85 450 to 85 550	1	1	1	1	1	0	1	1	0	1	0
85 550 to 85 650	1	1	1	1	1	0	1	1	0	1	1
85 650 to 85 750	1	1	1	1	1	0	1	1	0	0	1
85 750 to 85 850	1	1	1	1	1	0	0	1	0	0	1
85 850 to 85 950	1	1	1	1	1	0	0	1	0	1	1
85 950 to 86 050	1	1	1	1	1	0	0	1	0	1	0
86 050 to 86 150	1	1	1	1	1	0	0	1	1	1	0
86 150 to 86 250	1	1	1	1	1	0	0	1	1	0	0
86 250 to 86 350	1	1	1	1	1	0	0	0	1	0	0
86 350 to 86 450	1	1	1	1	1	0	0	0	1	1	0
86 450 to 86 550	1	1	1	1	1	0	0	0	0	1	0
86 550 to 86 650	1	1	1	1	1	0	0	0	0	1	1
86 650 to 86 750	1	1	1	1	1	0	0	0	0	0	1
86 750 to 86 850	1	1	1	0	1	0	0	0	0	0	1
86 850 to 86 950	1	1	1	0	1	0	0	0	0	1	1
86 950 to 87 050	1	1	1	0	1	0	0	0	0	1	0
87 050 to 87 150	1	1	1	0	1	0	0	0	1	1	0
87 150 to 87 250	1	1	1	0	1	0	0	0	1	0	0
87 250 to 87 350	1	1	1	0	1	0	0	1	1	0	0
87 350 to 87 450	1	1	1	0	1	0	0	1	1	1	0
87 450 to 87 550	1	1	1	0	1	0	0	1	0	1	0
87 550 to 87 650	1	1	1	0	1	0	0	1	0	1	1
87 650 to 87 750	1	1	1	0	1	0	0	1	0	0	1
87 750 to 87 850	1	1	1	0	1	0	1	1	0	0	1
87 850 to 87 950	1	1	1	0	1	0	1	1	0	1	1
87 950 to 88 050	1	1	1	0	1	0	1	1	0	1	0
88 050 to 88 150	1	1	1	0	1	0	1	1	1	1	0
88 150 to 88 250	1	1	1	0	1	0	1	1	1	0	0
88 250 to 88 350	1	1	1	0	1	0	1	0	1	0	0
88 350 to 88 450	1	1	1	0	1	0	1	0	1	1	0
88 450 to 88 550	1	1	1	0	1	0	1	0	0	1	0
88 550 to 88 650	1	1	1	0	1	0	1	0	0	1	1
88 650 to 88 750	1	1	1	0	1	0	1	0	0	0	1
88 750 to 88 850	1	1	1	0	1	1	1	0	0	0	1
88 850 to 88 950	1	1	1	0	1	1	1	0	0	1	1
88 950 to 89 050	1	1	1	0	1	1	1	0	0	1	0
89 050 to 89 150	1	1	1	0	1	1	1	0	1	1	0
89 150 to 89 250	1	1	1	0	1	1	1	0	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
89 250 to 89 350	1	1	1	0	1	1	1	1	1	0	0
89 350 to 89 450	1	1	1	0	1	1	1	1	1	1	0
89 450 to 89 550	1	1	1	0	1	1	1	1	0	1	0
89 550 to 89 650	1	1	1	0	1	1	1	1	0	1	1
89 650 to 89 750	1	1	1	0	1	1	1	1	0	0	1
89 750 to 89 850	1	1	1	0	1	1	0	1	0	0	1
89 850 to 89 950	1	1	1	0	1	1	0	1	0	1	1
89 950 to 90 050	1	1	1	0	1	1	0	1	0	1	0
90 050 to 90 150	1	1	1	0	1	1	0	1	1	1	0
90 150 to 90 250	1	1	1	0	1	1	0	1	1	0	0
90 250 to 90 350	1	1	1	0	1	1	0	0	1	0	0
90 350 to 90 450	1	1	1	0	1	1	0	0	1	1	0
90 450 to 90 550	1	1	1	0	1	1	0	0	0	1	0
90 550 to 90 650	1	1	1	0	1	1	0	0	0	1	1
90 650 to 90 750	1	1	1	0	1	1	0	0	0	0	1
90 750 to 90 850	1	1	1	0	0	1	0	0	0	0	1
90 850 to 90 950	1	1	1	0	0	1	0	0	0	1	1
90 950 to 91 050	1	1	1	0	0	1	0	0	0	1	0
91 050 to 91 150	1	1	1	0	0	1	0	0	1	1	0
91 150 to 91 250	1	1	1	0	0	1	0	0	1	0	0
91 250 to 91 350	1	1	1	0	0	1	0	1	1	0	0
91 350 to 91 450	1	1	1	0	0	1	0	1	1	1	0
91 450 to 91 550	1	1	1	0	0	1	0	1	0	1	0
91 550 to 91 650	1	1	1	0	0	1	0	1	0	1	1
91 650 to 91 750	1	1	1	0	0	1	0	1	0	0	1
91 750 to 91 850	1	1	1	0	0	1	1	1	0	0	1
91 850 to 91 950	1	1	1	0	0	1	1	1	0	1	1
91 950 to 92 050	1	1	1	0	0	1	1	1	0	1	0
92 050 to 92 150	1	1	1	0	0	1	1	1	1	1	0
92 150 to 92 250	1	1	1	0	0	1	1	1	1	0	0
92 250 to 92 350	1	1	1	0	0	1	1	0	1	0	0
92 350 to 92 450	1	1	1	0	0	1	1	0	1	1	0
92 450 to 92 550	1	1	1	0	0	1	1	0	0	1	0
92 550 to 92 650	1	1	1	0	0	1	1	0	0	1	1
92 650 to 92 750	1	1	1	0	0	1	1	0	0	0	1
92 750 to 92 850	1	1	1	0	0	0	1	0	0	0	1
92 850 to 92 950	1	1	1	0	0	0	1	0	0	1	1
92 950 to 93 050	1	1	1	0	0	0	1	0	0	1	0
93 050 to 93 150	1	1	1	0	0	0	1	0	1	1	0
93 150 to 93 250	1	1	1	0	0	0	1	0	1	0	0
93 250 to 93 350	1	1	1	0	0	0	1	1	1	0	0
93 350 to 93 450	1	1	1	0	0	0	1	1	1	1	0
93 450 to 93 550	1	1	1	0	0	0	1	1	0	1	0
93 550 to 93 650	1	1	1	0	0	0	1	1	0	1	1
93 650 to 93 750	1	1	1	0	0	0	1	1	0	0	1
93 750 to 93 850	1	1	1	0	0	0	0	1	0	0	1
93 850 to 93 950	1	1	1	0	0	0	0	1	0	1	1
93 950 to 94 050	1	1	1	0	0	0	0	1	0	1	0
94 050 to 94 150	1	1	1	0	0	0	0	1	1	1	0
94 150 to 94 250	1	1	1	0	0	0	0	1	1	0	0
94 250 to 94 350	1	1	1	0	0	0	0	0	1	0	0
94 350 to 94 450	1	1	1	0	0	0	0	0	1	1	0
94 450 to 94 550	1	1	1	0	0	0	0	0	0	1	0
94 550 to 94 650	1	1	1	0	0	0	0	0	0	1	1
94 650 to 94 750	1	1	1	0	0	0	0	0	0	0	1
94 750 to 94 850	1	0	1	0	0	0	0	0	0	0	1
94 850 to 94 950	1	0	1	0	0	0	0	0	0	1	1
94 950 to 95 050	1	0	1	0	0	0	0	0	0	1	0
95 050 to 95 150	1	0	1	0	0	0	0	0	1	1	0
95 150 to 95 250	1	0	1	0	0	0	0	0	1	0	0
95 250 to 95 350	1	0	1	0	0	0	0	1	1	0	0
95 350 to 95 450	1	0	1	0	0	0	0	1	1	1	0
95 450 to 95 550	1	0	1	0	0	0	0	1	0	1	0
95 550 to 95 650	1	0	1	0	0	0	0	1	0	1	1
95 650 to 95 750	1	0	1	0	0	0	0	1	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
95 750 to 95 850	1	0	1	0	0	0	1	1	0	0	1
95 850 to 95 950	1	0	1	0	0	0	1	1	0	1	1
95 950 to 96 050	1	0	1	0	0	0	1	1	0	1	0
96 050 to 96 150	1	0	1	0	0	0	1	1	1	1	0
96 150 to 96 250	1	0	1	0	0	0	1	1	1	0	0
96 250 to 96 350	1	0	1	0	0	0	1	0	1	0	0
96 350 to 96 450	1	0	1	0	0	0	1	0	1	1	0
96 450 to 96 550	1	0	1	0	0	0	1	0	0	1	0
96 550 to 96 650	1	0	1	0	0	0	1	0	0	1	1
96 650 to 96 750	1	0	1	0	0	0	1	0	0	0	1
96 750 to 96 850	1	0	1	0	0	1	1	0	0	0	1
96 850 to 96 950	1	0	1	0	0	1	1	0	0	1	1
96 950 to 97 050	1	0	1	0	0	1	1	0	0	1	0
97 050 to 97 150	1	0	1	0	0	1	1	0	1	1	0
97 150 to 97 250	1	0	1	0	0	1	1	0	1	0	0
97 250 to 97 350	1	0	1	0	0	1	1	1	1	0	0
97 350 to 97 450	1	0	1	0	0	1	1	1	1	1	0
97 450 to 97 550	1	0	1	0	0	1	1	1	0	1	0
97 550 to 97 650	1	0	1	0	0	1	1	1	0	1	1
97 650 to 97 750	1	0	1	0	0	1	1	1	0	0	1
97 750 to 97 850	1	0	1	0	0	1	0	1	0	0	1
97 850 to 97 950	1	0	1	0	0	1	0	1	0	1	1
97 950 to 98 050	1	0	1	0	0	1	0	1	0	1	0
98 050 to 98 150	1	0	1	0	0	1	0	1	1	1	0
98 150 to 98 250	1	0	1	0	0	1	0	1	1	0	0
98 250 to 98 350	1	0	1	0	0	1	0	0	1	0	0
98 350 to 98 450	1	0	1	0	0	1	0	0	1	1	0
98 450 to 98 550	1	0	1	0	0	1	0	0	0	1	0
98 550 to 98 650	1	0	1	0	0	1	0	0	0	1	1
98 650 to 98 750	1	0	1	0	0	1	0	0	0	0	1
98 750 to 98 850	1	0	1	0	1	1	0	0	0	0	1
98 850 to 98 950	1	0	1	0	1	1	0	0	0	1	1
98 950 to 99 050	1	0	1	0	1	1	0	0	0	1	0
99 050 to 99 150	1	0	1	0	1	1	0	0	1	1	0
99 150 to 99 250	1	0	1	0	1	1	0	0	1	0	0
99 250 to 99 350	1	0	1	0	1	1	0	1	1	0	0
99 350 to 99 450	1	0	1	0	1	1	0	1	1	1	0
99 450 to 99 550	1	0	1	0	1	1	0	1	0	1	0
99 550 to 99 650	1	0	1	0	1	1	0	1	0	1	1
99 650 to 99 750	1	0	1	0	1	1	0	1	0	0	1
99 750 to 99 850	1	0	1	0	1	1	1	1	0	0	1
99 850 to 99 950	1	0	1	0	1	1	1	1	0	1	1
99 950 to 100 050	1	0	1	0	1	1	1	1	0	1	0
100 050 to 100 150	1	0	1	0	1	1	1	1	1	1	0
100 150 to 100 250	1	0	1	0	1	1	1	1	1	0	0
100 250 to 100 350	1	0	1	0	1	1	1	0	1	0	0
100 350 to 100 450	1	0	1	0	1	1	1	0	1	1	0
100 450 to 100 550	1	0	1	0	1	1	1	0	0	1	0
100 550 to 100 650	1	0	1	0	1	1	1	0	0	1	1
100 650 to 100 750	1	0	1	0	1	1	1	0	0	0	1
100 750 to 100 850	1	0	1	0	1	0	1	0	0	0	1
100 850 to 100 950	1	0	1	0	1	0	1	0	0	1	1
100 950 to 101 050	1	0	1	0	1	0	1	0	0	1	0
101 050 to 101 150	1	0	1	0	1	0	1	0	1	1	0
101 150 to 101 250	1	0	1	0	1	0	1	0	1	0	0
101 250 to 101 350	1	0	1	0	1	0	1	1	1	0	0
101 350 to 101 450	1	0	1	0	1	0	1	1	1	1	0
101 450 to 101 550	1	0	1	0	1	0	1	1	0	1	0
101 550 to 101 650	1	0	1	0	1	0	1	1	0	1	1
101 650 to 101 750	1	0	1	0	1	0	1	1	0	0	1
101 750 to 101 850	1	0	1	0	1	0	0	1	0	0	1
101 850 to 101 950	1	0	1	0	1	0	0	1	0	1	1
101 950 to 102 050	1	0	1	0	1	0	0	1	0	1	0
102 050 to 102 150	1	0	1	0	1	0	0	1	1	1	0
102 150 to 102 250	1	0	1	0	1	0	0	1	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
102 250 to 102 350	1	0	1	0	1	0	0	0	1	0	0
102 350 to 102 450	1	0	1	0	1	0	0	0	1	1	0
102 450 to 102 550	1	0	1	0	1	0	0	0	0	1	0
102 550 to 102 650	1	0	1	0	1	0	0	0	0	1	1
102 650 to 102 750	1	0	1	0	1	0	0	0	0	0	1
102 750 to 102 850	1	0	1	1	1	0	0	0	0	0	1
102 850 to 102 950	1	0	1	1	1	0	0	0	0	1	1
102 950 to 103 050	1	0	1	1	1	0	0	0	0	1	0
103 050 to 103 150	1	0	1	1	1	0	0	0	1	1	0
103 150 to 103 250	1	0	1	1	1	0	0	0	1	0	0
103 250 to 103 350	1	0	1	1	1	0	0	1	1	0	0
103 350 to 103 450	1	0	1	1	1	0	0	1	1	1	0
103 450 to 103 550	1	0	1	1	1	0	0	1	0	1	0
103 550 to 103 650	1	0	1	1	1	0	0	1	0	1	1
103 650 to 103 750	1	0	1	1	1	0	0	1	0	0	1
103 750 to 103 850	1	0	1	1	1	0	1	1	0	0	1
103 850 to 103 950	1	0	1	1	1	0	1	1	0	1	1
103 950 to 104 050	1	0	1	1	1	0	1	1	0	1	0
104 050 to 104 150	1	0	1	1	1	0	1	1	1	1	0
104 150 to 104 250	1	0	1	1	1	0	1	1	1	0	0
104 250 to 104 350	1	0	1	1	1	0	1	0	1	0	0
104 350 to 104 450	1	0	1	1	1	0	1	0	1	1	0
104 450 to 104 550	1	0	1	1	1	0	1	0	0	1	0
104 550 to 104 650	1	0	1	1	1	0	1	0	0	1	1
104 650 to 104 750	1	0	1	1	1	0	1	0	0	0	1
104 750 to 104 850	1	0	1	1	1	1	1	0	0	0	1
104 850 to 104 950	1	0	1	1	1	1	1	0	0	1	1
104 950 to 105 050	1	0	1	1	1	1	1	0	0	1	0
105 050 to 105 150	1	0	1	1	1	1	1	0	1	1	0
105 150 to 105 250	1	0	1	1	1	1	1	0	1	0	0
105 250 to 105 350	1	0	1	1	1	1	1	1	1	0	0
105 350 to 105 450	1	0	1	1	1	1	1	1	1	1	0
105 450 to 105 550	1	0	1	1	1	1	1	1	0	1	0
105 550 to 105 650	1	0	1	1	1	1	1	1	0	1	1
105 650 to 105 750	1	0	1	1	1	1	1	1	0	0	1
105 750 to 105 850	1	0	1	1	1	1	0	1	0	0	1
105 850 to 105 950	1	0	1	1	1	1	0	1	0	1	1
105 950 to 106 050	1	0	1	1	1	1	0	1	0	1	0
106 050 to 106 150	1	0	1	1	1	1	0	1	1	1	0
106 150 to 106 250	1	0	1	1	1	1	0	1	1	0	0
106 250 to 106 350	1	0	1	1	1	1	0	0	1	0	0
106 350 to 106 450	1	0	1	1	1	1	0	0	1	1	0
106 450 to 106 550	1	0	1	1	1	1	0	0	0	1	0
106 550 to 106 650	1	0	1	1	1	1	0	0	0	1	1
106 650 to 106 750	1	0	1	1	1	1	0	0	0	0	1
106 750 to 106 850	1	0	1	1	0	1	0	0	0	0	1
106 850 to 106 950	1	0	1	1	0	1	0	0	0	1	1
106 950 to 107 050	1	0	1	1	0	1	0	0	0	1	0
107 050 to 107 150	1	0	1	1	0	1	0	0	1	1	0
107 150 to 107 250	1	0	1	1	0	1	0	0	1	0	0
107 250 to 107 350	1	0	1	1	0	1	0	1	1	0	0
107 350 to 107 450	1	0	1	1	0	1	0	1	1	1	0
107 450 to 107 550	1	0	1	1	0	1	0	1	0	1	0
107 550 to 107 650	1	0	1	1	0	1	0	1	0	1	1
107 650 to 107 750	1	0	1	1	0	1	0	1	0	0	1
107 750 to 107 850	1	0	1	1	0	1	1	1	0	0	1
107 850 to 107 950	1	0	1	1	0	1	1	1	0	1	1
107 950 to 108 050	1	0	1	1	0	1	1	1	0	1	0
108 050 to 108 150	1	0	1	1	0	1	1	1	1	1	0
108 150 to 108 250	1	0	1	1	0	1	1	1	1	0	0
108 250 to 108 350	1	0	1	1	0	1	1	0	1	0	0
108 350 to 108 450	1	0	1	1	0	1	1	0	1	1	0
108 450 to 108 550	1	0	1	1	0	1	1	0	0	1	0
108 550 to 108 650	1	0	1	1	0	1	1	0	0	1	1
108 650 to 108 750	1	0	1	1	0	1	1	0	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
108 750 to 108 850	1	0	1	1	0	0	1	0	0	0	1
108 850 to 108 950	1	0	1	1	0	0	1	0	0	1	1
108 950 to 109 050	1	0	1	1	0	0	1	0	0	1	0
109 050 to 109 150	1	0	1	1	0	0	1	0	1	1	0
109 150 to 109 250	1	0	1	1	0	0	1	0	1	0	0
109 250 to 109 350	1	0	1	1	0	0	1	1	1	0	0
109 350 to 109 450	1	0	1	1	0	0	1	1	1	1	0
109 450 to 109 550	1	0	1	1	0	0	1	1	0	1	0
109 550 to 109 650	1	0	1	1	0	0	1	1	0	1	1
109 650 to 109 750	1	0	1	1	0	0	1	1	0	0	1
109 750 to 109 850	1	0	1	1	0	0	0	1	0	0	1
109 850 to 109 950	1	0	1	1	0	0	0	1	0	1	1
109 950 to 110 050	1	0	1	1	0	0	0	1	0	1	0
110 050 to 110 150	1	0	1	1	0	0	0	1	1	1	0
110 150 to 110 250	1	0	1	1	0	0	0	1	1	0	0
110 250 to 110 350	1	0	1	1	0	0	0	0	1	0	0
110 350 to 110 450	1	0	1	1	0	0	0	0	1	1	0
110 450 to 110 550	1	0	1	1	0	0	0	0	0	1	0
110 550 to 110 650	1	0	1	1	0	0	0	0	0	1	1
110 650 to 110 750	1	0	1	1	0	0	0	0	0	0	1
110 750 to 110 850	1	0	0	1	0	0	0	0	0	0	1
110 850 to 110 950	1	0	0	1	0	0	0	0	0	1	1
110 950 to 111 050	1	0	0	1	0	0	0	0	0	1	0
111 050 to 111 150	1	0	0	1	0	0	0	0	1	1	0
111 150 to 111 250	1	0	0	1	0	0	0	0	1	0	0
111 250 to 111 350	1	0	0	1	0	0	0	1	1	0	0
111 350 to 111 450	1	0	0	1	0	0	0	1	1	1	0
111 450 to 111 550	1	0	0	1	0	0	0	1	0	1	0
111 550 to 111 650	1	0	0	1	0	0	0	1	0	1	1
111 650 to 111 750	1	0	0	1	0	0	0	1	0	0	1
111 750 to 111 850	1	0	0	1	0	0	1	1	0	0	1
111 850 to 111 950	1	0	0	1	0	0	1	1	0	1	1
111 950 to 112 050	1	0	0	1	0	0	1	1	0	1	0
112 050 to 112 150	1	0	0	1	0	0	1	1	1	1	0
112 150 to 112 250	1	0	0	1	0	0	1	1	1	0	0
112 250 to 112 350	1	0	0	1	0	0	1	0	1	0	0
112 350 to 112 450	1	0	0	1	0	0	1	0	1	1	0
112 450 to 112 550	1	0	0	1	0	0	1	0	0	1	0
112 550 to 112 650	1	0	0	1	0	0	1	0	0	1	1
112 650 to 112 750	1	0	0	1	0	0	1	0	0	0	1
112 750 to 112 850	1	0	0	1	0	1	1	0	0	0	1
112 850 to 112 950	1	0	0	1	0	1	1	0	0	1	1
112 950 to 113 050	1	0	0	1	0	1	1	0	0	1	0
113 050 to 113 150	1	0	0	1	0	1	1	0	1	1	0
113 150 to 113 250	1	0	0	1	0	1	1	0	1	0	0
113 250 to 113 350	1	0	0	1	0	1	1	1	1	0	0
113 350 to 113 450	1	0	0	1	0	1	1	1	1	1	0
113 450 to 113 550	1	0	0	1	0	1	1	1	0	1	0
113 550 to 113 650	1	0	0	1	0	1	1	1	0	1	1
113 650 to 113 750	1	0	0	1	0	1	1	1	0	0	1
113 750 to 113 850	1	0	0	1	0	1	0	1	0	0	1
113 850 to 113 950	1	0	0	1	0	1	0	1	0	1	1
113 950 to 114 050	1	0	0	1	0	1	0	1	0	1	0
114 050 to 114 150	1	0	0	1	0	1	0	1	1	1	0
114 150 to 114 250	1	0	0	1	0	1	0	1	1	0	0
114 250 to 114 350	1	0	0	1	0	1	0	0	1	0	0
114 350 to 114 450	1	0	0	1	0	1	0	0	1	1	0
114 450 to 114 550	1	0	0	1	0	1	0	0	0	1	0
114 550 to 114 650	1	0	0	1	0	1	0	0	0	1	1
114 650 to 114 750	1	0	0	1	0	1	0	0	0	0	1
114 750 to 114 850	1	0	0	1	1	1	0	0	0	0	1
114 850 to 114 950	1	0	0	1	1	1	0	0	0	1	1
114 950 to 115 050	1	0	0	1	1	1	0	0	0	1	0
115 050 to 115 150	1	0	0	1	1	1	0	0	1	1	0
115 150 to 115 250	1	0	0	1	1	1	0	0	1	0	0

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
115 250 to 115 350	1	0	0	1	1	1	0	1	1	0	0
115 350 to 115 450	1	0	0	1	1	1	0	1	1	1	0
115 450 to 115 550	1	0	0	1	1	1	0	1	0	1	0
115 550 to 115 650	1	0	0	1	1	1	0	1	0	1	1
115 650 to 115 750	1	0	0	1	1	1	0	1	0	0	1
115 750 to 115 850	1	0	0	1	1	1	1	1	0	0	1
115 850 to 115 950	1	0	0	1	1	1	1	1	0	1	1
115 950 to 116 050	1	0	0	1	1	1	1	1	0	1	0
116 050 to 116 150	1	0	0	1	1	1	1	1	1	1	0
116 150 to 116 250	1	0	0	1	1	1	1	1	1	0	0
116 250 to 116 350	1	0	0	1	1	1	1	0	1	0	0
116 350 to 116 450	1	0	0	1	1	1	1	0	1	1	0
116 450 to 116 550	1	0	0	1	1	1	1	0	0	1	0
116 550 to 116 650	1	0	0	1	1	1	1	0	0	1	1
116 650 to 116 750	1	0	0	1	1	1	1	0	0	0	1
116 750 to 116 850	1	0	0	1	1	0	1	0	0	0	1
116 850 to 116 950	1	0	0	1	1	0	1	0	0	1	1
116 950 to 117 050	1	0	0	1	1	0	1	0	0	1	0
117 050 to 117 150	1	0	0	1	1	0	1	0	1	1	0
117 150 to 117 250	1	0	0	1	1	0	1	0	1	0	0
117 250 to 117 350	1	0	0	1	1	0	1	1	1	0	0
117 350 to 117 450	1	0	0	1	1	0	1	1	1	1	0
117 450 to 117 550	1	0	0	1	1	0	1	1	0	1	0
117 550 to 117 650	1	0	0	1	1	0	1	1	0	1	1
117 650 to 117 750	1	0	0	1	1	0	1	1	0	0	1
117 750 to 117 850	1	0	0	1	1	0	0	1	0	0	1
117 850 to 117 950	1	0	0	1	1	0	0	1	0	1	1
117 950 to 118 050	1	0	0	1	1	0	0	1	0	1	0
118 050 to 118 150	1	0	0	1	1	0	0	1	1	1	0
118 150 to 118 250	1	0	0	1	1	0	0	1	1	0	0
118 250 to 118 350	1	0	0	1	1	0	0	0	1	0	0
118 350 to 118 450	1	0	0	1	1	0	0	0	1	1	0
118 450 to 118 550	1	0	0	1	1	0	0	0	0	1	0
118 550 to 118 650	1	0	0	1	1	0	0	0	0	1	1
118 650 to 118 750	1	0	0	1	1	0	0	0	0	0	1
118 750 to 118 850	1	0	0	0	1	0	0	0	0	0	1
118 850 to 118 950	1	0	0	0	1	0	0	0	0	1	1
118 950 to 119 050	1	0	0	0	1	0	0	0	0	1	0
119 050 to 119 150	1	0	0	0	1	0	0	0	1	1	0
119 150 to 119 250	1	0	0	0	1	0	0	0	1	0	0
119 250 to 119 350	1	0	0	0	1	0	0	1	1	0	0
119 350 to 119 450	1	0	0	0	1	0	0	1	1	1	0
119 450 to 119 550	1	0	0	0	1	0	0	1	0	1	0
119 550 to 119 650	1	0	0	0	1	0	0	1	0	1	1
119 650 to 119 750	1	0	0	0	1	0	0	1	0	0	1
119 750 to 119 850	1	0	0	0	1	0	1	1	0	0	1
119 850 to 119 950	1	0	0	0	1	0	1	1	0	1	1
119 950 to 120 050	1	0	0	0	1	0	1	1	0	1	0
120 050 to 120 150	1	0	0	0	1	0	1	1	1	1	0
120 150 to 120 250	1	0	0	0	1	0	1	1	1	0	0
120 250 to 120 350	1	0	0	0	1	0	1	0	1	0	0
120 350 to 120 450	1	0	0	0	1	0	1	0	1	1	0
120 450 to 120 550	1	0	0	0	1	0	1	0	0	1	0
120 550 to 120 650	1	0	0	0	1	0	1	0	0	1	1
120 650 to 120 750	1	0	0	0	1	0	1	0	0	0	1
120 750 to 120 850	1	0	0	0	1	1	1	0	0	0	1
120 850 to 120 950	1	0	0	0	1	1	1	0	0	1	1
120 950 to 121 050	1	0	0	0	1	1	1	0	0	1	0
121 050 to 121 150	1	0	0	0	1	1	1	0	1	1	0
121 150 to 121 250	1	0	0	0	1	1	1	0	1	0	0
121 250 to 121 350	1	0	0	0	1	1	1	1	1	0	0
121 350 to 121 450	1	0	0	0	1	1	1	1	1	1	0
121 450 to 121 550	1	0	0	0	1	1	1	1	0	1	0
121 550 to 121 650	1	0	0	0	1	1	1	1	0	1	1
121 650 to 121 750	1	0	0	0	1	1	1	1	0	0	1

Table B (cont.)

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
INCREMENTS (*Feet*)	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
121 750 to 121 850	1	0	0	0	1	1	0	1	0	0	1
121 850 to 121 950	1	0	0	0	1	1	0	1	0	1	1
121 950 to 122 050	1	0	0	0	1	1	0	1	0	1	0
122 050 to 122 150	1	0	0	0	1	1	0	1	1	1	0
122 150 to 122 250	1	0	0	0	1	1	0	1	1	0	0
122 250 to 122 350	1	0	0	0	1	1	0	0	1	0	0
122 350 to 122 450	1	0	0	0	1	1	0	0	1	1	0
122 450 to 122 550	1	0	0	0	1	1	0	0	0	1	0
122 550 to 122 650	1	0	0	0	1	1	0	0	0	1	1
122 650 to 122 750	1	0	0	0	1	1	0	0	0	0	1
122 750 to 122 850	1	0	0	0	0	1	0	0	0	0	1
122 850 to 122 950	1	0	0	0	0	1	0	0	0	1	1
122 950 to 123 050	1	0	0	0	0	1	0	0	0	1	0
123 050 to 123 150	1	0	0	0	0	1	0	0	1	1	0
123 150 to 123 250	1	0	0	0	0	1	0	0	1	0	0
123 250 to 123 350	1	0	0	0	0	1	0	1	1	0	0
123 350 to 123 450	1	0	0	0	0	1	0	1	1	1	0
123 450 to 123 550	1	0	0	0	0	1	0	1	0	1	0
123 550 to 123 650	1	0	0	0	0	1	0	1	0	1	1
123 650 to 123 750	1	0	0	0	0	1	0	1	0	0	1
123 750 to 123 850	1	0	0	0	0	1	1	1	0	0	1
123 850 to 123 950	1	0	0	0	0	1	1	1	0	1	1
123 950 to 124 050	1	0	0	0	0	1	1	1	0	1	0
124 050 to 124 150	1	0	0	0	0	1	1	1	1	1	0
124 150 to 124 250	1	0	0	0	0	1	1	1	1	0	0
124 250 to 124 350	1	0	0	0	0	1	1	0	1	0	0
124 350 to 124 450	1	0	0	0	0	1	1	0	1	1	0
124 450 to 124 550	1	0	0	0	0	1	1	0	0	1	0
124 550 to 124 650	1	0	0	0	0	1	1	0	0	1	1
124 650 to 124 750	1	0	0	0	0	1	1	0	0	0	1
124 750 to 124 850	1	0	0	0	0	0	1	0	0	0	1
124 850 to 124 950	1	0	0	0	0	0	1	0	0	1	1
124 950 to 125 050	1	0	0	0	0	0	1	0	0	1	0
125 050 to 125 150	1	0	0	0	0	0	1	0	1	1	0
125 150 to 125 250	1	0	0	0	0	0	1	0	1	0	0
125 250 to 125 350	1	0	0	0	0	0	1	1	1	0	0
125 350 to 125 450	1	0	0	0	0	0	1	1	1	1	0
125 450 to 125 550	1	0	0	0	0	0	1	1	0	1	0
125 550 to 125 650	1	0	0	0	0	0	1	1	0	1	1
125 650 to 125 750	1	0	0	0	0	0	1	1	0	0	1
125 750 to 125 850	1	0	0	0	0	0	0	1	0	0	1
125 850 to 125 950	1	0	0	0	0	0	0	1	0	1	1
125 950 to 126 050	1	0	0	0	0	0	0	1	0	1	0
126 050 to 126 150	1	0	0	0	0	0	0	1	1	1	0
126 150 to 126 250	1	0	0	0	0	0	0	1	1	0	0
126 250 to 126 350	1	0	0	0	0	0	0	0	1	0	0
126 350 to 126 450	1	0	0	0	0	0	0	0	1	1	0
126 450 to 126 550	1	0	0	0	0	0	0	0	0	1	0
126 550 to 126 650	1	0	0	0	0	0	0	0	0	1	1
126 650 to 126 750	1	0	0	0	0	0	0	0	0	0	1

Table C. Allowable DME/P errors

Location	*Standard*	*Mode*	*PFE*	*CMN*
37 km (20 NM) to 9.3 km (5 NM) from MLS approach reference datum	1 and 2	IA	±250 m (±820 ft) reducing linearly to ±85 m (±279 ft)	±68 m (±223 ft) reducing linearly to ±34 m (±111 ft)
9.3 km (5 NM) to MLS approach reference datum	1	FA	±85 m (±279 ft) reducing linearly to ±30 m (±100 ft)	±18 m (±60 ft)
	2	FA	±85 m (±279 ft) reducing linearly to ±12 m (±40 ft)	±12 m (±40 ft)
	See Note	IA	±100 m (±328 ft)	±68 m (±223 ft)
At MLS approach reference datum and through runway coverage	1	FA	±30 m (±100 ft)	±18 m (±60 ft)
	2	FA	±12 m (±40 ft)	±12 m (±40 ft)
Throughout back azimuth coverage volume	1 and 2	FA	±100 m (±328 ft)	±68 m (±223 ft)
	See Note	IA	±100 m (±328 ft)	±68 m (±223 ft)

Note.— At distances from 9.3 km (5 NM) to the MLS approach reference datum and throughout the back azimuth coverage the IA mode may be used when the FA mode is not operative.

CHAPTER 4. COMMUNICATION SYSTEMS

4.1 Definitions

Data signalling rate. Data signalling rate refers to the passage of information per unit of time, and is expressed in bits/second. Data signalling rate is given by the formula:

$$\sum_{i=1}^{i=m} \frac{1}{T_i} \log_2 n_i$$

where m is the number of parallel channels, T_i is the minimum interval for the ith channel expressed in seconds, n_i is the number of significant conditions of the modulation in the i th channel.

Note 1.—

a) For a single channel (serial transmission) it reduces to $(1/T)\log_2 n$; *with a two-condition modulation* $(n=2)$, *it is* $1/T$.

b) For a parallel transmission with equal minimum intervals and equal number of significant conditions on each channel, it is $m(1/T)\log_2 n$ *(*$m(1/T)$ *in case of a two-condition modulation).*

Note 2.— In the above definition, the term "parallel channels" is interpreted to mean: channels, each of which carries an integral part of an information unit, e.g. the parallel transmission of bits forming a character. In the case of a circuit comprising a number of channels, each of which carries information "independently", with the sole purpose of increasing the traffic handling capacity, these channels are not to be regarded as parallel channels in the context of this definition.

Degree of standardized test distortion. The degree of distortion of the restitution measured during a specific period of time when the modulation is perfect and corresponds to a specific text.

Effective margin. That margin of an individual apparatus which could be measured under actual operating conditions.

Low modulation rates. Modulation rates up to and including 300 bauds.

Margin. The maximum degree of distortion of the circuit at the end of which the apparatus is situated which is compatible with the correct translation of all the signals which it may possibly receive.

Medium modulation rates. Modulation rates above 300 and up to and including 3 000 bauds.

Modulation rate. The reciprocal of the unit interval measured in seconds. This rate is expressed in bauds.

Note.— Telegraph signals are characterized by intervals of time of duration equal to or longer than the shortest or unit interval. The modulation rate (formerly telegraph speed) is therefore expressed as the inverse of the value of this unit interval. If, for example, the unit interval is 20 milliseconds, the modulation rate is 50 bauds.

SELCAL system. A system which permits the selective calling of individual aircraft over radiotelephone channels linking a ground station with the aircraft.

Synchronous operation. Operation in which the time interval between code units is a constant.

4.2 Technical provisions relating to teletypewriter apparatus and circuits used in the AFTN

4.2.1 In international teletypewriter circuits of the AFTN, using a 5-unit code, the International Telegraph Alphabet No. 2 shall be used only to the extent prescribed in 4.1.2 of Volume II.

4.2.2 In international teletypewriter circuits of the AFTN, using a 7-unit code, the International Telegraph Alphabet No. 3 shall be used only to the extent prescribed in 4.1.2 of Volume II.

Note.— Table 4-1 indicates the 5-unit code (International Telegraph Alphabet No. 2) and 7-unit code (International Telegraph Alphabet No. 3) and their interrelationship.

4.2.3 **Recommendation.—** *In so far as it is practicable, the modulation rate should be 50 bauds; where a rate of 50 bauds is not practicable, the rate should be determined by bilateral or multilateral agreement between the Administrations concerned.*

4.2.4 **Recommendation.—** *The nominal duration of the transmitting cycle should be at least 7.4 units (preferably 7.5), the stop element lasting for at least 1.4 units (preferably 1.5).*

4.2.4.1 **Recommendation.—** *The receiver should be able to translate correctly in service the signals coming from a transmitter with a nominal transmitting cycle of 7 units.*

4.2.5 **Recommendation.—** *Apparatus in service should be maintained and adjusted in such a manner that its net effective margin is never less than 35 per cent.*

4.2.6 **Recommendation.—** *The number of characters which the textual line of the page-printing apparatus may contain should be fixed at 69.*

Table 4-1. International Telegraph Alphabets No. 2 and No. 3

Number of Signal	*Letter Case*	*Figure Case*	*Impulses*			
			5-unit code			*7-unit code*
			Start	12345	Stop	
				International Code No. 2		*International Code No. 3*
1	A	—	A	ZZAAA	Z	AAZZAZA
2	B	?	A	ZAAZZ	Z	AAZZAAZ
3	C	:	A	AZZZA	Z	ZAAZZAA
4	D	(1)	A	ZAAZA	Z	AAZZZAA
5	E	3	A	ZAAAA	Z	AZZZAAA
6	F		A	ZAZZA	Z	AAZAAZZ
7	G		A	AZAZZ	Z	ZZAAAAZ
8	H		A	AAZAZ	Z	ZAZAAZA
9	I	8	A	AZZAA	Z	ZZZAAAA
10	J	Attention signal	A	ZZAZA	Z	AZAAAZZ
11	K	(	A	ZZZZA	Z	AAAZAZZ
12	L	)	A	AZAAZ	Z	ZZAAAZA
13	M	.	A	AAZZZ	Z	ZAZAAAZ
14	N	,	A	AAZZA	Z	ZAZAZAA
15	O	9	A	AAAZZ	Z	ZAAAZZA
16	P	0	A	AZZAZ	Z	ZAAZAZA
17	Q	1	A	ZZZAZ	Z	AAAZZAZ
18	R	4	A	AZAZA	Z	ZZAAZAA
19	S	'	A	ZAZAA	Z	AZAZAZA
20	T	5	A	AAAAZ	Z	ZAAAZAZ
21	U	7	A	ZZZAA	Z	AZZAAZA
22	V	=	A	AZZZZ	Z	ZAAZAAZ
23	W	2	A	ZZAAZ	Z	AZAAZAZ
24	X	/	A	ZAZZZ	Z	AAZAZZA
25	Y	6	A	ZAZAZ	Z	AAZAZAZ
26	Z	+	A	ZAAAZ	Z	AZZAAAZ
27	carriage return		A	AAAZA	Z	ZAAAAZZ
28	line feed		A	AZAAA	Z	ZAZZAAA
29	letters		A	ZZZZZ	Z	AAAZZZA
30	figures		A	ZZAZZ	Z	AZAAZZA
31	space		A	AAZAA	Z	ZZAZAAA
32	unperforated tape		A	AAAAA	Z	AAAAZZZ
33	signal repetition					AZZAZAA
34	signal α					AZAZAAZ
35	signal β					AZAZZAA

Sign	*Closed circuit*	*Double current*
A	No current	Negative current
Z	Positive current	Positive current

(1) Used for answer-back facility.

4.2.7 **Recommendation.**— *In start-stop apparatus fitted with automatic time delay switches, the disconnexion of the power supply to the motor should not take place before the lapse of at least 45 seconds after the reception of the last signal.*

4.2.8 **Recommendation.**— *Arrangements should be made to avoid the mutilation of signals transmitted at the head of a message and received on start-stop reperforating apparatus.*

4.2.8.1 **Recommendation.**— *If the reperforating apparatus is provided with local means for feeding the paper, not more than one mutilated signal should be tolerated.*

4.2.9 **Recommendation.**— *Complete circuits should be so engineered and maintained that their degree of standardized test distortion does not exceed 28 per cent on the standardized text:*

THE QUICK BROWN FOX JUMPS
OVER THE LAZY DOG

or

VOYEZ LE BRICK GEANT QUE
JEXAMINE PRES DU WHARF

4.2.10 **Recommendation.**— *The degree of isochronous distortion on the standardized text of each of the parts of a complete circuit should be as low as possible, and in any case should not exceed 10 per cent.*

4.2.11 **Recommendation.**— *The over-all distortion in transmitting equipment used on teletypewriter channels should not exceed 5 per cent.*

4.2.12 **Recommendation.**— *AFTN circuits should be equipped with a system of continuous check of channel condition. Additionally, controlled circuit protocols should be applied.*

Note.— Guidance material on systems of continuous check of channel condition and on low speed ITA-2 controlled circuit protocols are contained in Attachment D to Part I.

4.3 Terminal equipment associated with aeronautical radioteletypewriter channels operating in the band 2.5 MHz to 30 MHz

4.3.1 Selection of type of modulation and code

4.3.1.1 **Recommendation.**— *Frequency shift modulation (F1B) should be employed in radioteletypewriter systems used in the aeronautical fixed service (AFS), except where the characteristics of four-frequency shift modulation (F7B) or the independent sideband (ISB) method of operation are of advantage.*

Note 1.— F1B type of modulation is accomplished by shifting a radio frequency carrier between two frequencies representing "position A" (start signal polarity) and "position Z" (stop signal polarity) of the start-stop 5-unit telegraphic code.

Note 2.— Material providing information and guidance on the use of F7B and ISB appears in Attachment D to Part I.

4.3.1.2 **Recommendation.**— *When the use of unprotected 5-unit telegraphic code on a radio circuit of the AFS results in an intolerable error rate, equipment for automatic error corrections should be provided.*

4.3.1.2.1 **Recommendation.**— *When the provisions of 4.3.1.2 above are applicable, consideration should be given to the 7-unit automatic error correction system conforming to the International Telegraph and Telephone Consultative Committee (CCITT) recommendations for such systems, except where special circumstances exist in which the particular qualities of the 5-unit automatic error correction system are of advantage.*

Note 1.— The existing recommendations are recorded in Recommendation 5 of the CCITT Orange Book, Volume VII, "Telegraph Technique" — 1976.

Note 2.— Material providing information and guidance on automatic error correction systems appears in Attachment D to Part I.

4.3.2 System characteristics

4.3.2.1 **Recommendation.**— *The characteristics of signals from radioteletypewriter transmitters utilizing F1B modulation should be as follows:*

a) Frequency shift: *the lowest possible value, chosen from the alternatives 200 Hz, 400 Hz and 500 Hz, as conditions permit.*

Note.— The conditions influencing the selection of one of the above values are generally:

1) the length of the circuit and propagation conditions;

2) the number of channels and modulation rate generally used;

3) the quality of equipment.

b) Frequency shift tolerance: *within plus or minus 3 per cent of the nominal value of the frequency shift.*

c) Polarity:

1) single channel circuits: *the higher frequency corresponds to "position A" (start signal polarity);*

2) multichannel 7-unit ARQ-equipped circuits:

— *on directly keyed channels (e.g. channel A of a 2-channel system), the higher frequency corresponds to "position A" (start signal polarity);*

— *on channels having reversed keying (e.g. channel B of a 2-channel system), the higher frequency corresponds to "position Z" (stop signal polarity).*

4.3.2.2 **Recommendation.**— *The variation of the mean between the radio frequencies representing respectively "position A" and "position Z" should not exceed 100 Hz during any two-hour period.*

4.3.2.3 **Recommendation.**— *The over-all distortion of the teletypewriter signal, as monitored at the output of the radio transmitter or in its immediate vicinity, should not exceed 10 per cent.*

Note.— Such distortion means the displacement in time of the transitions between elements from their proper positions, expressed as a percentage of unit element time.

4.3.2.4 **Recommendation.**— *Radioteletypewriter receivers concerned with F1B modulation should be capable of operating satisfactorily on signals having the characteristics set out in 4.3.2.1 and 4.3.2.2 above.*

4.3.2.5 **Recommendation.**— *The characteristics of multichannel transmission of teletypewriter signals over a radio circuit should be established by agreement between the Administrations concerned.*

Note.— Material providing information and guidance on the establishment of radioteletypewriter circuits in accordance with good engineering practice appears in Attachment D to Part I.

4.3.2.6 **Recommendation.**— *Where independent sideband systems are employed to provide radioteletypewriter channels for the AFS, together with one or more voice channels, in the same circuit, the characteristics of the system should be in conformity with those recommended by the International Radio Consultative Committee (CCIR) for such systems.*

Note 1.— The existing recommendations are recorded in Recommendations 348-2 and 349-3 of the CCIR XIVth Plenary Assembly (Kyoto, 1978).

Note 2.— Material providing information and guidance on the use of independent sideband operation appears in Attachment D to Part I.

4.4 Teletypewriter broadcast systems in the band 110 kHz to 130 kHz

4.4.1 If a ground-to-air teletypewriter broadcast system in the band 110 kHz to 130 kHz is installed and maintained, it shall conform to the following specifications:

4.4.1.1 Frequency shift modulation (F1B) shall be employed.

Note.— This type of modulation is accomplished by shifting a radio frequency carrier between two frequencies representing "position A" (start signal polarity) and "position Z" (stop signal polarity) of the telegraphic code.

4.4.1.2 The difference between the frequencies associated with the marking and spacing elements shall be 60 Hz and shall be maintained within plus or minus 3 Hz of that value.

4.4.1.3 The radio frequency associated with "position A" shall be higher than that associated with "position Z".

4.4.1.4 The deviation of the mean between the radio frequencies representing respectively "position A" and "position Z" from the assigned frequency shall not exceed 3 Hz.

4.4.1.5 The over-all distortion of the teletypewriter signal, as monitored at the output of the radio transmitter or in its immediate vicinity, shall not exceed 2 per cent.

Note.— Such distortion means the displacement in time of the transitions between elements from their proper positions, expressed as a percentage of unit element time.

4.4.1.6 The modulation rate shall be 50 bauds.

4.4.1.7 The nominal duration of the transmitting cycle shall be between the limits of 7.4 and 7.5 units; the duration of the stop element shall be between 1.4 and 1.5 units.

4.5 Air-ground VHF communication system characteristics

4.5.1 The characteristics of the air-ground VHF communication system used in the International Aeronautical Mobile Service shall be in conformity with the following specifications:

4.5.1.1 Radiotelephone emissions shall be continuous wave (CW) amplitude modulated carriers (A3E).

4.5.1.2 Spurious emissions shall be kept at the lowest value which the state of technique and the nature of the service permit.

Note.— Appendix 8 to the Radio Regulations contains the tolerances for the levels of spurious emissions to which transmitters must conform in accordance with RR 304.

4.5.1.3 The radio frequencies used shall be selected from the radio frequencies in the band 117.975 MHz to 136 MHz and the band 136 MHz to 137 MHz subject to the conditions of Radio Regulation 595. The separation between assignable frequencies (channel spacing) and frequency tolerances applicable to elements of the system shall be as specified in Part II, 4.1.2 and 4.1.6.

Note.— The band 117.975 MHz to 132 MHz was allocated to the Aeronautical Mobile (R) Service in the Radio Regulations (1947). By subsequent revisions of the Regulations at ITU World Administrative Conferences the bands 132 MHz to 136 MHz and 136 MHz to 137 MHz were added to the (R) allocation under conditions which differ for ITU Regions, or for specified countries or combinations of countries.

4.5.1.4 The design polarization of emissions shall be vertical.

4.6 System characteristics of the ground installation

4.6.1 Transmitting function

4.6.1.1 *Frequency stability.* The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced in accordance with Part II, 4.1.2, the radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

Note.— The above tolerances will not be suitable for off-set carrier systems.

4.6.1.1.1 *Off-set carrier systems.* The stability of individual carriers of an off-set carrier system shall be such as to prevent first order heterodyne frequencies of less than 4 kHz and, additionally, the maximum frequency excursion of the outer carrier frequencies from the assigned carrier frequency shall not exceed 8 kHz.

Note.— Examples of the required stability of the individual carriers of off-set carrier systems may be found at Attachment D to Part I, 2.2.

4.6.1.2 *Power.*

Recommendation.— *On a high percentage of occasions, the effective radiated power should be such as to provide a field strength of a least 75 microvolts per metre (minus 109 dBW/m²) within the defined operational coverage of the facility, on the basis of free space propagation.*

4.6.1.3 *Modulation.* A peak modulation factor of at least 0.85 shall be achievable.

4.6.1.4 **Recommendation.**— *Means should be provided to maintain the average modulation factor at the highest practicable value without overmodulation.*

4.6.2. Receiving function

4.6.2.1 *Sensitivity.* After due allowance has been made for feeder loss and antenna polar diagram variation, the sensitivity of the receiving function shall be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 20 microvolts per metre (minus 120 dBW/m²) or more.

4.6.2.2 *Effective acceptance bandwidth.* The receiving system shall provide an adequate and intelligible audio output when the signal specified at 4.6.2.1 above has a carrier frequency within plus or minus 0.005 per cent of the assigned frequency.

4.6.2.3 *Adjacent channel rejection.* The receiving system shall ensure an effective rejection of 60 dB or more at the next assignable channel.

Note.— The next assignable frequency will normally be plus or minus 50 kHz. Where this channel spacing will not suffice, the next assignable frequency will be plus or minus 25 kHz implemented in accordance with the provisions of Part II, 4.1.2. It is recognized that in certain areas of the world receivers designed for 50 kHz or 100 kHz channel spacing may continue to be used.

4.7 System characteristics of the airborne installation

4.7.1 Transmitting function

4.7.1.1 *Frequency stability.* The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.003 per cent from the assigned frequency.

4.7.1.2 *Power.* On a high percentage of occasions, the effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/m²) on the basis of free space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated.

4.7.1.3 *Modulation.* A peak modulation factor of at least 0.85 shall be achievable.

4.7.1.4 **Recommendation.**— *Means should be provided to maintain the average modulation factor at the highest practicable value without overmodulation.*

4.7.2 Receiving function

4.7.2.1 *Sensitivity.*

Recommendation.— *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 an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 75 microvolts per metre (minus 109 dBW/m²).*

Note.— For planning extended range VHF facilities, an airborne receiving function sensitivity of 30 microvolts per metre may be assumed.

4.7.2.2 *Effective acceptance bandwidth for 100 kHz, 50 kHz and 25 kHz channel spacing receiving installations.* The receiving function shall ensure an effective acceptance bandwidth as follows:

a) in areas where off-set carrier systems are employed, the receiving function shall provide an adequate audio output when the signal specified at 4.7.2.1 above has a carrier frequency within 8 kHz of the assigned frequency;

b) in areas where off-set carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified at 4.7.2.1 above has a carrier frequency within plus or minus 0.005 per cent of the assigned frequency.

4.7.2.3 *Adjacent channel rejection.* The receiving function shall ensure an effective adjacent channel rejection as follows:

a) *25 kHz channel spacing environment:* 50 dB or more at plus or minus 25 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 17 kHz;

b) *50 kHz channel spacing environment:* 50 dB or more at plus or minus 50 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 35 kHz;

c) *100 kHz channel spacing environment:* 50 dB or more at plus or minus 100 kHz with respect to the assigned frequency.

4.7.2.4 **Recommendation.**— *Whenever practicable, the receiving system should ensure an effective adjacent channel rejection characteristic of 60 dB or more at plus or minus 25 kHz, 50 kHz and 100 kHz from the assigned frequency for receiving systems intended to operate in channel spacing environments of 25 kHz, 50 kHz and 100 kHz respectively.*

Note.— Frequency planning is normally based on an assumption of 60 dB effective adjacent channel rejection at plus or minus 25 kHz, 50 kHz or 100 kHz from the assigned frequency as appropriate to the channel spacing environment.

4.7.2.5 **Recommendation.**— *In the case of receivers complying with 4.7.2.2 above used in areas where off-set carrier systems are in force, the characteristics of the receiver should be such that:*

a) the audio frequency response precludes harmful levels of audio heterodynes resulting from the reception of two or more off-set carrier frequencies;

b) the receiver muting circuits, if provided, operate satisfactorily in the presence of audio heterodynes resulting from the reception of two or more off-set carrier frequencies.

4.7.3 Interference immunity performance

4.7.3.1 After 1 January 1998, the VHF communications receiving system shall provide satisfactory performance in the presence of two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

4.7.3.2 After 1 January 1998, the VHF communications receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

Note.— Guidance material on immunity criteria to be used for the performance quoted in 4.7.3.1 and 4.7.3.2 above is contained in Attachment D to Part I, 2.3.

4.7.3.3 After 1 January 1995, all new installations of airborne VHF communications receiving systems shall meet the provisions of 4.7.3.1 and 4.7.3.2 above.

4.7.3.4 **Recommendation.**— *Airborne VHF communications receiving systems meeting the immunity performance Standards of 4.7.3.1 and 4.7.3.2 above should be placed into operation at the earliest possible date.*

4.8 SELCAL system

4.8.1 **Recommendation.**— *Where a SELCAL system is installed, the following system characteristics should be applied:*

a) Transmitted code. *Each transmitted code should be made up of two consecutive tone pulses, with each pulse containing two simultaneously transmitted tones. The pulses should be of 1.0 plus or minus 0.25 seconds duration, separated by an interval of 0.2 plus or minus 0.1 second.*

b) Stability. *The frequency of transmitted tones should be held to plus or minus 0.15 per cent tolerance to ensure proper operation of the airborne decoder.*

c) Distortion. *The over-all audio distortion present on the transmitted RF signal should not exceed 15 per cent.*

d) Per cent modulation. *The RF signal transmitted by the ground radio station should contain, within 3 dB, equal amounts of the two modulating tones. The combination of tones should result in a modulation envelope having a nominal modulation percentage as high as possible and in no case less than 60 per cent.*

e) Transmitted tones. *Tone codes should be made up of various combinations of the tones listed in the following table and designated by colour and letter as indicated:*

Designation	*Frequency (Hz)*
Red A	312.6
Red B	346.7
Red C	384.6
Red D	426.6
Red E	473.2
Red F	524.8
Red G	582.1
Red H	645.7
Red J	716.1
Red K	794.3
Red L	881.0
Red M	977.2
Red P	1 083.9
Red Q	1 202.3
Red R	1 333.5
Red S	1 479.1

Note 1.— It should be noted that the tones are spaced by Log^{-1} *0.045 to avoid the possibility of harmonic combinations.*

Note 2.— In accordance with the application principles developed by the Sixth Session of the Communications Division, the only codes at present used internationally are selected from the red group.

Note 3.— Guidance material on the use of SELCAL systems is contained in Attachment D to Part I.

Note 4.— The tones Red P, Red Q, Red R, and Red S are applicable after 1 September 1985, in accordance with 4.8.2 below.

4.8.2 As from 1 September 1985, aeronautical stations which are required to communicate with SELCAL-equipped aircraft shall have SELCAL encoders in accordance with the red group in the table of tone frequencies of 4.8.1 above. After 1 September 1985, SELCAL codes using the tones Red P, Red Q, Red R, and Red S may be assigned.

4.9 System practices

4.9.1 Stations in an AFTN group

4.9.1.1 *Group control station — Selection.* When an AFTN group has been established, one of the constituent stations shall be designated to undertake the functions of the group control station, except that, where necessary, supplementary arrangements for the exercise of the control of communications over the group may be made by mutual agreement between the group control station and the stations of the group concerned.

Note.— The designation of the group control station is normally made by regional meetings when drawing up plans for the AFTN.

4.9.1.2 *Group control station — Functions.* An AFTN group control station shall endeavour to ensure:

a) the expeditious passing of communications between stations of the group;

b) that there is efficient operation and good radio discipline in the group, and that communications between stations are not restricted, except when intervention by the group control station is necessary to regulate or stop transmissions which might affect the efficient operation and discipline of the group;

c) the application of current ICAO procedures by all stations within the group;

d) that the times of change of actual frequencies for the group are determined and co-ordinated (taking into account propagation data, operating conditions, and frequencies authorized for the use of stations in the group), e.g. changes from day to night frequencies;

e) that arrangements are made for such of the following as may become necessary:

1) the answering of calls;

2) the acceptance, and forwarding of communications;

3) the notification of communications;

addressed to stations experiencing difficulties in communication or absent from group watch.

4.9.1.3 *Duties of stations other than the group control station*

4.9.1.3.1 **Recommendation.—** *Stations of an AFTN group that are not able to change frequencies at the time indicated should notify the group control station of the time at which they expect to be able to effect the change.*

4.9.1.3.2 **Recommendation.—** *Stations of an AFTN group that are unable to continue guarding the working frequency of the group should notify the group control station accordingly, stating, if possible, the time of return to watch.*

4.10 Technical provisions relating to ATS message transmission

4.10.1 *Interconnexion by direct or omnibus channels — low modulation rates — 5-unit code.*

Note.— See 4.12 below for medium modulation rates.

4.10.1.1 **Recommendation.—** *AFTN techniques (cf. 4.2 above) should be used.*

4.11 Single sideband (SSB) HF communication system characteristics for use in the aeronautical mobile service

4.11.1 The characteristics of the air-ground HF SSB system, where used in the Aeronautical Mobile Service, shall be in conformity with the following specifications:

4.11.1.1 *Frequency range*

4.11.1.1.1 HF SSB installations shall be capable of operation at any SSB carrier (reference) frequency available to the Aeronautical Mobile (R) Service in the band 2.8 MHz to 22 MHz and necessary to meet the approved assignment plan for the region(s) in which the system is intended to operate, and in compliance with the relevant provisions of the Radio Regulations.

Note 1.— See Introduction to Chapter 3, Part II and Figures 4-1 and 4-2.

Note 2.— The Extraordinary Administrative Radio Conference (EARC), Geneva, 1966, established an Allotment Plan (Appendix 27 to the Radio Regulations). The ITU World Administrative Radio Conference, Aeronautical Mobile (R) Service, Geneva, 1978, established a new Allotment Plan (Appendix 27, Aer2 to the Radio Regulations).

4.11.1.1.2 The equipment shall be capable of operating on integral multiples of 1 kHz.

4.11.1.2 *Sideband selection*

4.11.1.2.1 The sideband transmitted shall be that on the higher frequency side of its carrier (reference) frequency.

4.11.1.3 *Carrier (reference) frequency*

4.11.1.3.1 Until 1 February 1983 channel utilization shall be in conformity with the Allotment Plan in either Appendix 27 EARC* or Appendix 27 Aer2** as follows:

a) where Appendix 27 EARC channels are used the carrier (reference) frequency shall in the case of the upper half of the previous DSB channel be the same as the carrier (reference) frequency of that channel;

b) where Appendix 27 EARC channels are used the carrier (reference) frequency shall in the case of the lower half of the previous DSB channel be 3 kHz lower than the carrier (reference) frequency of that channel;

c) where Appendix 27 Aer2 channels are used the carrier (reference) frequency shall be in conformity with the table at 27/16 of Appendix 27 Aer2.

4.11.1.3.2 With effect from 1 February 1983 channel utilization shall be in conformity with the table of carrier (reference) frequencies at 27/16 and the Allotment Plan at 27/186 to 27/207 inclusive (or frequencies established on the basis of 27/21, as may be appropriate) of Appendix 27 Aer2.

Note.— It is intended that only the carrier (reference) frequency be promulgated in Regional Plans and Aeronautical Publications.

4.11.1.4 *Classes of emission and carrier suppression*

4.11.1.4.1 The system shall utilize the suppressed carrier class of emission J3E (also J7B and J9B as applicable). When SELCAL is employed as specified in 4.8 above, the installation shall utilize class H2B emission.

4.11.1.4.2 By 1 February 1982 aeronautical stations and aircraft stations shall have introduced the appropriate class(es) of emission prescribed in 4.11.1.4.1 above. Effective this date the use of class A3E emission shall be discontinued except as provided in 4.11.1.4.4 below.

4.11.1.4.3 Until 1 February 1982 aeronautical stations and aircraft stations equipped for single sideband operations shall also be equipped to transmit class H3E emission where required to be compatible with reception by double sideband equipment. Effective this date the use of class H3E emission shall be discontinued except as provided in 4.11.1.4.4 below.

4.11.1.4.4 **Recommendation.—** *For stations directly involved in co-ordinated search and rescue operations using the frequencies 3 023 kHz and 5 680 kHz, the class of emission J3E should be used; however, since maritime mobile and land mobile services may be involved, A3E and H3E classes of emission may be used.*

4.11.1.4.5 After 1 April 1981 no new DSB equipment shall be installed.

4.11.1.4.6 Aircraft station transmitters shall be capable of at least 26 dB carrier suppression with respect to peak envelope power (P_p) for classes of emission J3E, J7B or J9B.

4.11.1.4.7 Aeronautical station transmitters shall be capable of 40 dB carrier suppression with respect to peak envelope power (P_p) for classes of emission J3E, J7B or J9B.

4.11.1.5 *Audio frequency bandwidth*

4.11.1.5.1 For radiotelephone emissions the audio frequencies shall be limited to between 300 and 2 700 Hz and the occupied bandwidth of other authorized emissions shall not exceed the upper limit of J3E emissions. In specifying these limits, however, no restriction in their extension shall be implied in so far as emissions other than J3E are concerned, provided that the limits of unwanted emissions are met (see 4.11.1.7 below).

Note.— For aircraft and aeronautical station transmitter types first installed before 1 February 1983 the audio frequencies will be limited to 3 000 Hz.

4.11.1.5.2 For other authorized classes of emission the modulation frequencies shall be such that the required spectrum limits of 4.11.1.7 below will be met.

4.11.1.6 *Frequency tolerance*

4.11.1.6.1 The basic frequency stability of the transmitting function for classes of emission J3E, J7B or J9B shall be such that the difference between the actual carrier of the transmission and the carrier (reference) frequency shall not exceed:

— 20 Hz for airborne installations;

— 10 Hz for ground installations.

4.11.1.6.2 The basic frequency stability of the receiving function shall be such that, with the transmitting function stabilities specified in 4.11.1.6.1 above, the over-all frequency difference between ground and airborne functions achieved in service and including Doppler shift, does not exceed 45 Hz. However, a greater frequency difference shall be permitted in the case of supersonic aircraft.

* Appendix 27 EARC means Appendix 27 to the Radio Regulations (1968 Edition).

** Appendix 27 Aer2 means Appendix 27, as amended by the ITU World Administrative Radio Conference (1978).

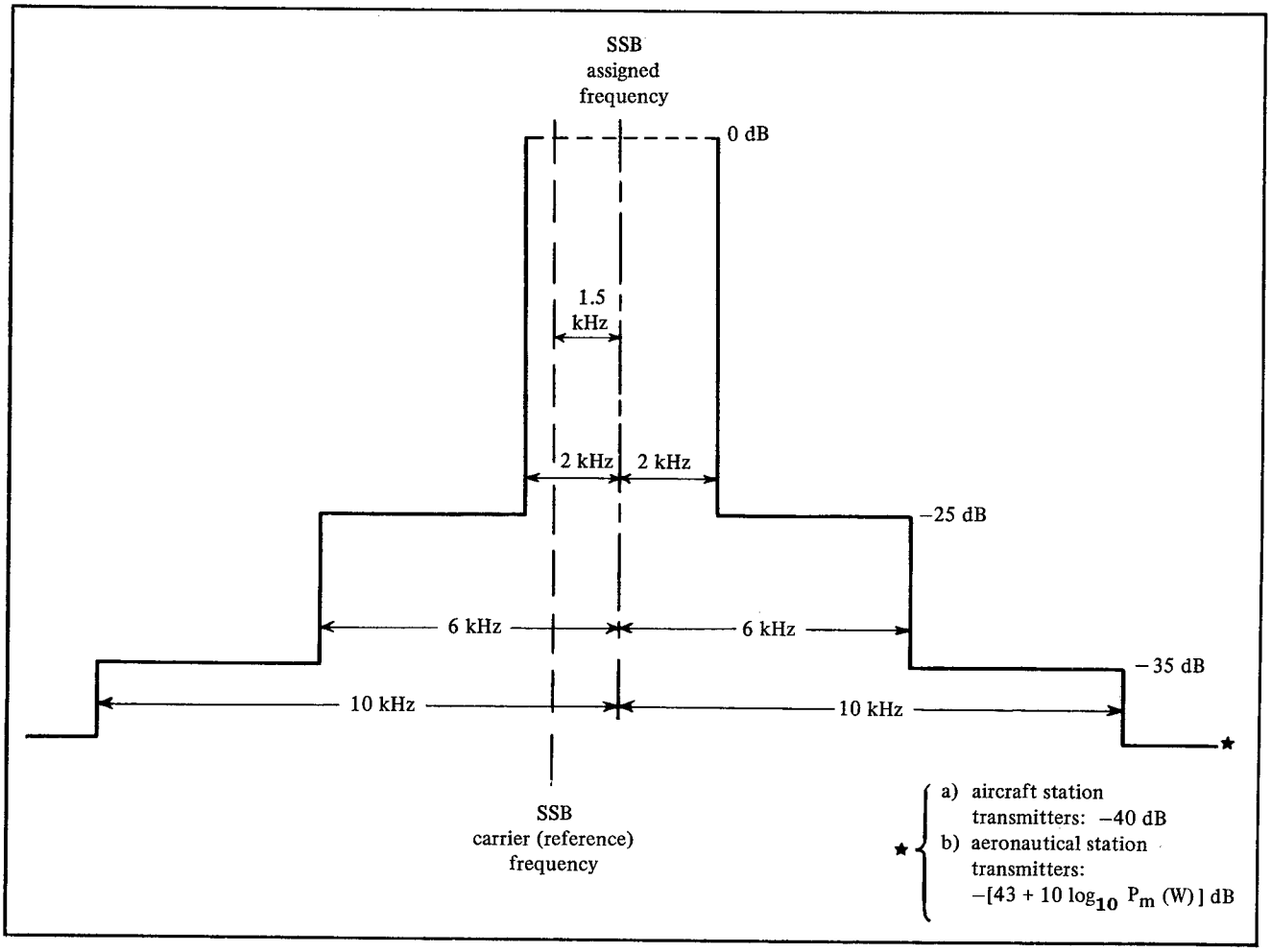


Figure 4-1. Required spectrum limits (in terms of mean power) for aircraft station transmitter types and for aeronautical station transmitters first installed before 1 February 1983

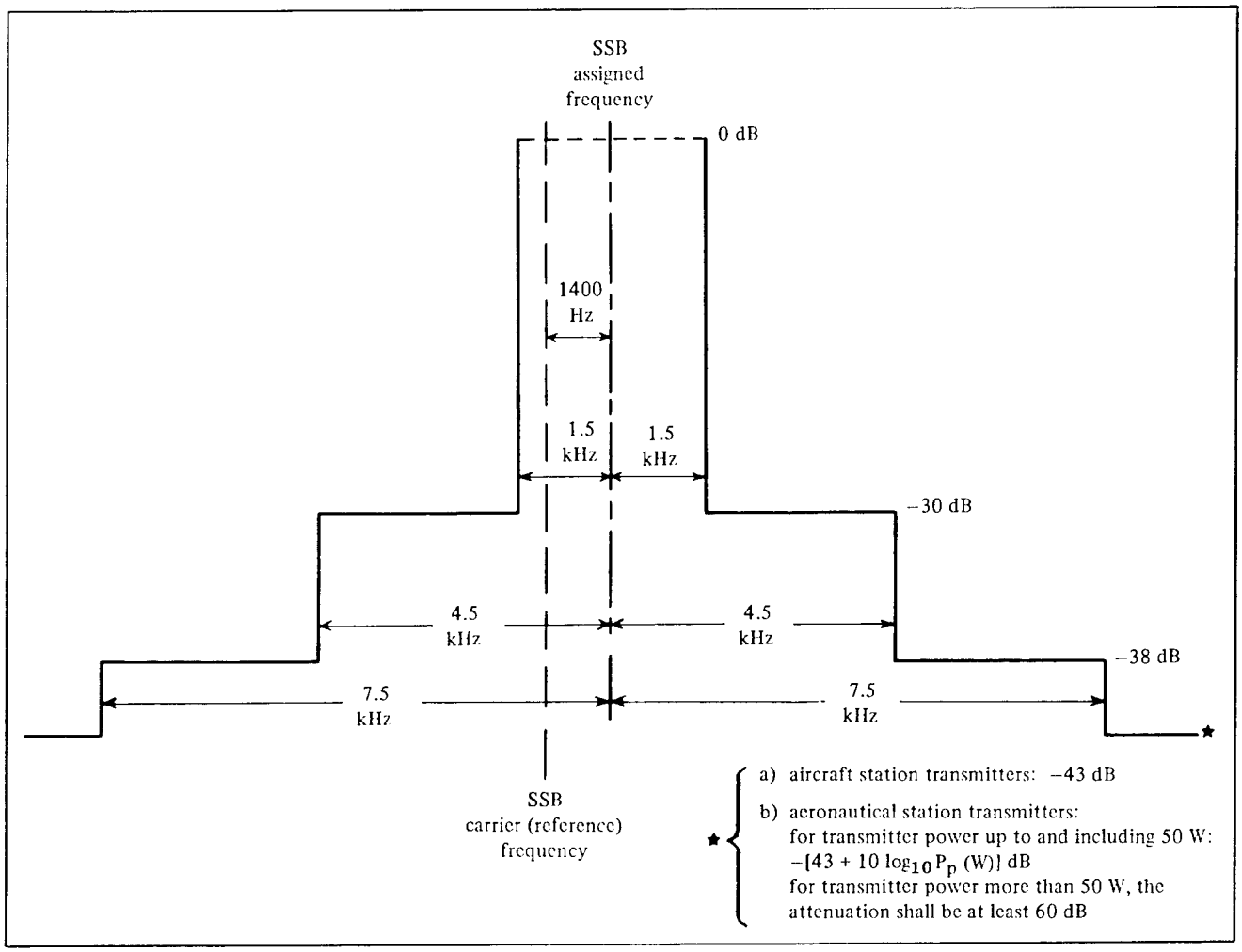


Figure 4-2. Required spectrum limits (in terms of peak power) for aircraft station transmitters first installed after 1 February 1983 and aeronautical station transmitters in use after 1 February 1983

4.11.1.7 *Spectrum limits*

4.11.1.7.1 For aircraft station transmitter types and for aeronautical station transmitters first installed before 1 February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B the mean power of any emission on any discrete frequency shall be less than the mean power (P_m) of the transmitter in accordance with the following:

— on any frequency removed by 2 kHz or more up to 6 kHz from the assigned frequency: at least 25 dB;

— on any frequency removed by 6 kHz or more up to 10 kHz from the assigned frequency: at least 35 dB;

— on any frequency removed from the assigned frequency by 10 kHz or more:

a) aircraft station transmitters: 40 dB;

b) aeronautical station transmitters:

$$[43 + 10 \log_{10} P_m \text{ (W)}] \text{ dB}$$

4.11.1.7.2 For aircraft station transmitters first installed after 1 February 1983 and for aeronautical station transmitters in use as of 1 February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B, the peak envelope power (P_p) of any emission on any discrete frequency shall be less than the peak envelope power (P_p) of the transmitter in accordance with the following:

— on any frequency removed by 1.5 kHz or more up to 4.5 kHz from the assigned frequency: at least 30 dB;

— on any frequency removed by 4.5 kHz or more up to 7.5 kHz from the assigned frequency: at least 38 dB;

— on any frequency removed from the assigned frequency by 7.5 kHz or more:

a) aircraft station transmitters: 43 dB;

b) aeronautical station transmitters: For transmitter power up to and including 50 W:

$$[43 + 10 \log_{10} P_p \text{ (W)}] \text{ dB}$$

For transmitter power more than 50 W: 60 dB.

Note.— See Figures 4-1 and 4-2.

4.11.1.8 *Power*

4.11.1.8.1 *Aeronautical station installations.* Except as permitted by the relevant provisions of Appendix 27 Aer2 to the Radio Regulations the peak envelope power (P_p) supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emissions shall not exceed a maximum value of 6 kW.

4.11.1.8.2 *Aircraft station installations.* The peak envelope power supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emission shall not exceed 400 W except as provided for in Appendix 27 Aer2 of the Radio Regulations as follows:

27/62 It is recognized that the power employed by aircraft transmitters may, in practice, exceed the limits specified in No. 27/54. However, the use of such increased power (which normally should not exceed 600 W P_p) shall not cause harmful interference to stations using frequencies in accordance with the technical principles on which the Allotment Plan is based.

27/54 Unless otherwise specified in Part II of this Appendix, the peak envelope powers supplied to the antenna transmission line shall not exceed the maximum values indicated in the table below; the corresponding peak effective radiated powers being assumed to be equal to two-thirds of these values:

Class of emission	*Stations*	*Max. peak envelope power* (P_p)
H2B, J3E, J7B, J9B, A3E*, H3E* (100% modulation)	Aeronautical stations Aircraft stations	6 kW 400 W
Other emission such as A1A, F1B	Aeronautical stations Aircraft stations	1.5 kW 100 W

* A3E and H3E to be used only on 3 023 kHz and 5 680 kHz, as well as in cases covered by Resolution No. 402.

4.11.1.9 *Method of operation.* Single channel simplex shall be employed.

4.12 Technical provisions relating to international ground-ground data interchange at medium and higher signalling rates

Note.— Throughout this paragraph in the context of coded character sets, the term "unit" means the unit of selective information, and is essentially equivalent to the term "bit".

4.12.1 General

4.12.1.1 **Recommendation.—** *In international data interchange of characters, a 7-unit coded character set providing a repertoire of 128 characters and designated as International Alphabet No. 5 (IA-5) should be used. Compatibility with the 5-unit coded character set of International Telegraph Alphabet No. 2 (ITA-2) should be ensured where applicable.*

4.12.1.2 When the provisions of 4.12.1.1 above are applied, International Alphabet No. 5 (IA-5) contained in Table 4-4 shall be used.

Table 4-2. Conversion from the International Telegraph Alphabet No. 2 (ITA-2) to the International Alphabet No. 5 (IA-5)

ITA-2 letter case of signal No.		*IA-5 column/row*		*ITA-2 figure case of signal No.*		*IA-5 column/row*	
1	A	4/1	A	1	–	2/13	–
2	B	4/2	B	2	?	3/15	?
3	C	4/3	C	3	:	3/10	:
4	D	4/4	D	4		3/15	?
5	E	4/5	E	5	3	3/3	3
6	F	4/6	F	6		3/15	?
7	G	4/7	G	7		3/15	?
8	H	4/8	H	8		3/15	?
9	I	4/9	I	9	8	3/8	8
10	J	4/10	J	10 Attention signal *(Note 3)*		0/7	Bel
11	K	4/11	K	11	(	2/8	(
12	L	4/12	L	12	)	2/9	)
13	M	4/13	M	13	.	2/14	.
14	N	4/14	N	14	,	2/12	,
15	O	4/15	O	15	9	3/9	9
16	P	5/0	P	16	0	3/0	0
17	Q	5/1	Q	17	1	3/1	1
18	R	5/2	R	18	4	3/4	4
19	S	5/3	S	19	'	2/7	'
20	T	5/4	T	20	5	3/5	5
21	U	5/5	U	21	7	3/7	7
22	V	5/6	V	22	=	3/13	=
23	W	5/7	W	23	2	3/2	2
24	X	5/8	X	24	/	2/15	/
25	Y	5/9	Y	25	6	3/6	6
26	Z	5/10	Z	26	+	2/11	+
27	CR	0/13	CR	27	CR	0/13	CR
28	LF	0/10	LF	28	LF	0/10	LF
29	LTRS	*		29	LTRS	*	
30	FIGS	*		30	FIGS	*	
31	SP	2/0	SP	31	SP	2/0	SP
32		*		32		*	

* *No conversion shall be made for these positions and the signal/character shall be removed from the data.*

Note 1.– The end-of-message signal NNNN (in letter and figure case) shall convert to ETX (0/3).

Note 2.– The start-of-message signal ZCZC (in letter and figure case) shall convert to SOH (0/1).

Note 3.– Figures case of Signal No. 10 shall only be converted upon detection of the AFTN priority alarm which shall convert to five occurrences of BEL (0/7).

Note 4.– When converting from ITA-2, a STX (0/2) character shall be inserted once at the beginning of the next line following detection of CR LF or LF CR at the end of the Origin Line.

Note 5.– The sequence of seven signal 28 (LF) shall convert to one VT (0/11) character.

Table 4-3. Conversion from the International Alphabet No. 5 (IA-5) to the International Telegraph Alphabet No. 2 (ITA-2)

Row \ Col.	0	1	2	3	4	5	6	7
0	*	*	31FL	16F	2F	16L	2F	16L
1	Note 5	*	2F	17F	1L	17L	1L	17L
2	*	*	2F	23F	2L	18L	2L	18L
3	Note 1	*	2F	5F	3L	19L	3L	19L
4	*	*	2F	18F	4L	20L	4L	20L
5	*	*	2F	20F	5L	21L	5L	21L
6	*	*	2F	25F	6L	22L	6L	22L
7	Note 2	*	19F	21F	7L	23L	7L	23L
8	*	*	11F	9F	8L	24L	8L	24L
9	*	*	12F	15F	9L	25L	9L	25L
10	28FL	*	2F	3F	10L	26L	10L	26L
11	Note 3	*	26F	2F	11L	2F	11L	2F
12	*	*	14F	2F	12L	2F	12L	2F
13	27FL	*	1F	22F	13L	2F	13L	2F
14	*	*	13F	2F	14L	2F	14L	2F
15	*	*	24F	2F	15L	2F	15L	*

* *No conversion shall be made for these positions and the signal/character shall be removed from the data.*

Example: *To find the ITA-2 signal to which the charater 3/6 of IA-5 is to be converted, look at column 3, row 6.*

25F means figure case of signal No. 25

(L = letter case, FL = either case designation).

Note 1.– *The character 0/3 (ETX) shall convert to the ITA-2 sequence signals 14L, 14L, 14L, 14L (NNNN).*

Note 2.– *The signal 0/7 (BEL) shall only be converted when a sequence of 5 occurrences is detected, which shall convert to the ITA-2 sequence signals 30, 10F, 10F, 10F, 10F, 10F, 29.*

Note 3.–

Note 3.– *The character sequence CR CR LF VT (0/11) ETX (0/3) shall convert to the ITA-2 sequence signals 29, 27, 27, 28, 28, 28, 28, 28, 28, 28, 28, 14L, 14L, 14L, 14L.*

Note 4.– *To prevent redundant generation of figure and letter characters in ITA-2 when converting from IA-5, no case designation shall be assigned to ITA-2 non-printing functions (signals No. 27, 28, 29, 30, 31).*

Note 5.– *The character 0/1 (SOH) shall convert to the ITA-2 sequence signals 26L, 3L, 26L, 3L (ZCZC).*

4.12.1.2.1 The serial transmission of units comprising an individual character of IA-5 shall be with the low order unit (b_1) transmitted first.

4.12.1.2.2 **Recommendation.**— *When IA-5 is used, each character should include an additional unit for parity in the eighth level position.*

4.12.1.2.3 When the provisions of 4.12.1.2.2 above are applied, the sense of the character parity bit shall produce even parity in links which operate on the start-stop principle, and odd parity in links using end-to-end synchronous operations.

4.12.1.2.4 Character-for-character conversion shall be as listed in Tables 4-2 and 4-3 for all characters which are authorized in the AFTN format for transmission on the AFS in both IA-5 and ITA-2.

4.12.1.2.5 Characters which appear in only one code set, or which are not authorized for transmission on the AFS shall be as depicted in the code conversion tables.

4.12.2 Data transmission characteristics

4.12.2.1 **Recommendation.**— *The data signalling rate should be chosen from among the following:*

600 bits/s	*4 800 bits/s*
1 200 bits/s	*9 600 bits/s*
2 400 bits/s	

4.12.2.2 **Recommendation.**— *The type of transmission for each data signalling rate should be chosen as follows:*

Data signalling rate	Type of transmission
600 bits/s	*Synchronous or asynchronous serial transmission*
1 200 bits/s	*Synchronous or asynchronous serial transmission*
2 400 bits/s	*Synchronous serial transmission*
4 800 bits/s	*Synchronous serial transmission*
9 600 bits/s	*Synchronous serial transmission*

4.12.2.3 **Recommendation.**— *The type of modulation for each data signalling rate should be chosen as follows:*

Data signalling rate	Type of modulation
600 bits/s	*Frequency*
1 200 bits/s	*Frequency*
2 400 bits/s	*Phase*
4 800 bits/s	*Phase*
9 600 bits/s	*Phase-amplitude*

Note.— This recommendation does not necessarily apply to ground-ground extensions of air-ground links used exclusively for the transfer of air-ground data, inasmuch as such circuits may be considered as part of the air-ground link.

4.12.2.4 *Character structure on data links*

4.12.2.4.1 Character parity shall not be used for error checking on CIDIN links. Parity appended to IA-5 coded characters per 4.12.1.2.2 above, prior to entry to the CIDIN shall be ignored. For messages exiting the CIDIN, parity shall be generated in accordance with 4.12.1.2.3 above.

4.12.2.4.2 Characters of less than eight bits in length shall be padded out to eight bits in length before assembly into the User Data Field (UDF) for transmission on CIDIN links. The padding bits shall occupy the higher order end of the octet, i.e. Bit 8, Bit 7 as required, and shall have the binary values 0.

4.12.2.5 When exchanging data over CIDIN links using bit-oriented procedures, the entry centre address, exit centre addresses and destination addresses in the Transport and CIDIN Packet Headers shall be in the IA-5 character set contained in Table 4-4.

4.12.2.6 **Recommendation.**— *When transmitting messages in AFTN format over CIDIN links using bit-oriented procedures, the messages should be in the IA-5 character set contained in Table 4-4.*

4.12.3 Ground-ground character-oriented data link control procedures

Note.— The provisions of this section pertain to ground-ground data interchange applications using IA-5 prescribed by 4.12.1 above and which employ the ten transmission control characters (SOH, STX, ETX, EOT, ENQ, ACK, DLE, NAK, SYN, and ETB) for data link control, over synchronous or asynchronous transmission facilities.

4.12.3.1 *Descriptions.* The following descriptions shall apply to data link applications contained in this section.

a) A master station is that station which has control of the data link at a given instant.

b) A slave station is one that has been selected to receive a transmission from the master station.

c) A control station is the single station on a multipoint link that is permitted to assume master status and deliver messages to one or more individually selected (non-control) tributary stations, or it is permitted to assign temporary master status to any of the other tributary stations.

4.12.3.2 *Message composition.*

a) A transmission shall consist of characters from IA-5 transmitted in accordance with 4.12.1.2.2 above and shall be either an information message or a supervisory sequence.

Table 4-4. International Alphabet No. 5 (IA-5)
(International Reference Version)

				b_7	0	0	0	0	1	1	1	1
				b_6	0	0	1	1	0	0	1	1
				b_5	0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1		0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	TC_7 (DLE)	SP	0	@	P	`	p
0	0	0	1	1	TC_1 (SOH)	DC_1	!	1	A	Q	a	q
0	0	1	0	2	TC_2 (STX)	DC_2	" ④	2	B	R	b	r
0	0	1	1	3	TC_3 (ETX)	DC_3	#	3	C	S	c	s
0	1	0	0	4	TC_4 (EOT)	DC_4	¤ ②	4	D	T	d	t
0	1	0	1	5	TC_5 (ENQ)	TC_8 (NAK)	%	5	E	U	e	u
0	1	1	0	6	TC_6 (ACK)	TC_9 (SYN)	&	6	F	V	f	v
0	1	1	1	7	BEL	TC_{10} (ETB)	' ④	7	G	W	g	w
1	0	0	0	8	FE_0 (BS)	CAN	(	8	H	X	h	x
1	0	0	1	9	FE_1 (HT)	EM	)	9	I	Y	i	y
1	0	1	0	10	FE_2 ① (LF)	SUB	*	:	J	Z	j	z
1	0	1	1	11	FE_3 (VT)	ESC	+	;	K	[	k	{
1	1	0	0	12	FE_4 (FF)	IS_4 (FS)	, ④	<	L	\	l	|
1	1	0	1	13	FE_5 ① (CR)	IS_3 (GS)	–	=	M	]	m	}
1	1	1	0	14	SO	IS_2 (RS)	.	>	N	^ ④	n	¯ ③
1	1	1	1	15	SI	IS_1 (US)	/	?	O	_	o	DEL

NOTES

Note 1.— The format effectors are intended for equipment in which horizontal and vertical movements are effected separately. If equipment requires the action of CARRIAGE RETURN to be combined with a vertical movement, the format effector for that vertical movement may be used to effect the combined movement. Use of FE 2 for a combined CR and LF operation is not allowed for international transmission on AFS networks.

Note 2.— The symbol ¤ does not designate the currency of a specific country.

Note 3.— Position 7/14 is used for graphic character ¯ (OVERLINE), the graphical representation of which may vary according to national use to represent (TILDE) or another diacritical sign provided that there is no risk of confusion with another graphic character included in the table.

Note 4.— The graphic characters in position 2/2, 2/7, 2/12 and 5/14 have respectively the significance of QUOTATION MARK, APOSTROPHE, COMMA and UPWARD ARROW HEAD; however, these characters take on the significance of the diacritical signs DIAERESIS, ACUTE ACCENT, CEDILLA and CIRCUMFLEX ACCENT when they are preceded or followed by the BACKSPACE character (0/8).

Note 5.— When graphical representation of the control characters of IA-5 is required, it is permissible to use the symbols specified in International Organization for Standardization (ISO) Standard 2047-1975.

Table 4-4 (cont.)

CONTROL CHARACTERS

Abbreviation	*Meaning*	*Position in the code table*
ACK	Acknowledge	0/6
BEL	Bell	0/7
BS	Backspace	0/8
CAN	Cancel	1/8
CR	Carriage return*	0/13
DC	Device control	—
DEL	Delete	7/15
DLE	Data link escape	1/0
EM	End of medium	1/9
ENQ	Enquiry	0/5
EOT	End of transmission	0/4
ESC	Escape	1/11
ETB	End of transmission block	1/7
ETX	End of text	0/3
FE	Format effector	—
FF	Form feed	0/12
FS	File separator	1/12
GS	Group separator	1/13
HT	Horizontal tabulation	0/9
IS	Information separator	—
LF	Line feed*	0/10
NAK	Negative acknowledge	1/5
NUL	Null	0/0
RS	Record separator	1/14
SI	Shift-in	0/15
SO	Shift-out	0/14
SOH	Start of heading	0/1
SP	Space	2/0
STX	Start of text	0/2
SUB	Substitute character	1/10
SYN	Synchronous idle	1/6
TC	Transmission control	—
US	Unit separator	1/15
VT	Vertical tabulation	0/11

GRAPHIC CHARACTERS

Graphic	*Note*	*Name*	*Position in the code table*
(space)		Space (*see* 7.2)	2/0
!		Exclamation mark	2/1
"	4	Quotation mark, Diaeresis	2/2
#		Number sign	2/3
¤	2	Currency sign	2/4
%		Percent sign	2/5
&		Ampersand	2/6
'	4	Apostrophe, Acute accent	2/7
(		Left parenthesis	2/8
)		Right parenthesis	2/9
*		Asterisk	2/10
+		Plus sign	2/11
,	4	Comma, Cedilla	2/12
—		Hyphen, Minus sign	2/13
.		Full stop (period)	2/14
/		Solidus	2/15
:		Colon	3/10
;		Semi-colon	3/11
<		Less-than sign	3/12
=		Equal sign	3/13
>		Greater-than sign	3/14
?		Question mark	3/15
@		Commercial 'at'	4/0
[		Left square bracket	5/11
\		Reverse solidus	5/12
]		Right square bracket	5/13
^	4	Upward arrow head, Circumflex accent	5/14
_		Underline	5/15
`		Grave accent	6/0
{		Left curly bracket	7/11
|		Vertical line	7/12
}		Right curly bracket	7/13
~	3	Overline, Tilde	7/14

* See Note 1.

DIACRITICAL SIGNS

In the character set, some printing symbols may be designed to permit their use for the composition of accented letters when necessary for general interchange of information. A sequence of three characters, comprising a letter, BACKSPACE and one of these symbols, is needed for this composition, and the symbol is then regarded as a diacritical sign. It should be noted that these symbols take on their diacritical significance only when they are preceded or followed by the BACKSPACE character; for example the symbol corresponding to the code combination 2/7 (') normally has the significance of APOSTROPHE, but becomes the diacritical sign ACUTE ACCENT when it precedes or follows the BACKSPACE character.

NAMES, MEANINGS AND FONTS OF GRAPHIC CHARACTERS

At least one name is assigned to denote each of the graphic characters. These names are intended to reflect their customary meanings and are not intended to define or restrict the meanings of graphic characters. No particular style or font design is specified for the graphic characters.

UNIQUENESS OF CHARACTER ALLOCATION

A character allocated to a position in the table may not be placed elsewhere in the table.

Table 4-4 (cont.)

FUNCTIONAL CHARACTERISTICS RELATED TO CONTROL CHARACTERS

Some definitions given below are stated in general terms and more explicit definitions of use may be needed for specific implementation of the code table on recording media or on transmission channels. These more explicit definitions and the use of these characters are the subject of ISO publications.

General designations of control characters

The general designation of control characters involves a specific class name followed by a subscript number.

They are defined as follows:

TC — *Transmission control characters* — Control characters intended to control or facilitate transmission of information over telecommunication networks.

The use of the TC characters on the general telecommunication networks is the subject of ISO publications.

The transmission control characters are:
ACK, DLE, ENQ, EOT, ETB, ETX, NAK, SOH, STX and SYN.

FE — *Formal effectors* — Control characters mainly intended for the control of the layout and positioning of information on printing and /or display devices. In the definitions of specific format effectors, any reference to printing devices should be interpreted as including display devices. The definitions of format effectors use the following concept:

a) a page is composed of a number of lines of characters;

b) the characters forming a line occupy a number of positions called character positions;

c) the active position is that character position in which the character about to be processed would appear if it were to be printed. The active position normally advances one character position at a time.

The format effector characters are:
BS, CR, FF, HT, LF and VT (see also Note 1 to Table 4-4.)

DC — *Device control characters* — Control characters for the control of a local or remote ancillary device (or devices) connected to a data processing and/or telecommunication system. These control characters are not intended to control telecommunication systems; this should be achieved by the use of TCs.

Certain preferred uses of the individual DCs are given below under *Specific control characters.*

IS — *Information separators* — Control characters that are used to separate and qualify data logically. There are four such characters. They may be used either in hierarchical order or non-hierarchically; in the latter case their specific meanings depend on their applications.

When they are used hierarchically, the ascending order is:
US, RS, GS, FS.

In this case data normally delimited by a particular separator cannot be split by a higher order separator but will be considered as delimited by any higher order separator.

Specific control characters

Individual members of the classes of controls are sometimes referred to by their abbreviated class name and a subscript number (e.g. TC_5) and sometimes by a specific name indicative of their use (e.g. ENQ).

Different but related meanings may be associated with some of the control characters but in an interchange of data this normally requires agreement between the sender and the recipient.

ACK — *Acknowledge* — A transmission control character transmitted by a receiver as an affirmative response to the sender.

BEL — *Bell* — A control character that is used when there is a need to call for attention; it may control alarm or attention devices.

BS — *Backspace* — A format effector which moves the active position one character position backwards on the same line.

CAN — *Cancel* — A character, or the first character of a sequence, indicating that the data preceding it are in error. As a result these data are to be ignored. The specific meaning of this character must be defined for each application and/or between sender and recipient.

CR — *Carriage return* — A format effector which moves the active position to the first character position on the same line.

Device controls

DC_1 — A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to restore a device to the basic mode of operation (*see also* DC_2 and DC_3), or for any other device control function not provided by other DCs.

DC_2 — A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to set a device to a special mode of operation (in which case DC_1 is used to restore the device to the basic mode), or for any other device control function not provided by other DCs.

DC_3 — A device control character which is primarily intended for turning off or stopping an ancillary device. This function may be a secondary level stop, e.g. wait, pause, stand-by or halt (in which case DC_1 is used to restore normal operation). If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

DC_4 — A device control character which is primarily intended for turning off, stopping or interrupting an ancillary device. If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

Examples of use of the device controls

1) One switching
   on — DC_2 off — DC_4

2) Two independent switchings
   First one on — DC_2 off — DC_4
   Second one on — DC_1 off — DC_3

3) Two dependent switchings
   General on — DC_2 off — DC_4
   Particular on — DC_1 off — DC_3

4) Input and output switching
   Output on — DC_2 off — DC_4
   Input on — DC_1 off — DC_3

DEL — *Delete* — A character used primarily to erase or obliterate an erroneous or unwanted character in punched tape. DEL characters may also serve to accomplish media-fill or time-fill. They may be inserted into or removed from a stream of data without affecting the information content of that stream, but then the addition or removal of these characters may affect the information layout and/or the control of equipment.

Table 4-4 (cont.)

DLE — *Data link escape* — A transmission control character which will change the meaning of a limited number of contiguously following characters. It is used exclusively to provide supplementary data transmission control functions. Only graphic characters and transmission control characters can be used in DLE sequences.

EM — *End of medium* — A control character that may be used to identify the physical end of a medium, or the end of the used portion of a medium, or the end of the wanted portion of data recorded on a medium. The position of this character does not necessarily correspond to the physical end of the medium.

ENQ — *Enquiry* — A transmission control character used as a request for a response from a remote station — the response may include station identification and/or station status. When a "Who are you?" function is required on the general switched transmission network, the first use of ENQ after the connection is established shall have the meaning "Who are you?" (station identification). Subsequent use of ENQ may, or may not, include the function "Who are you?", as determined by agreement.

EOT — *End of transmission* — A transmission control character used to indicate the conclusion of the transmission of one or more texts.

ESC — *Escape* — A control character which is used to provide an additional control function. It alters the meaning of a limited number of contiguously following bit combinations which constitute the escape sequence.

Escape sequences are used to obtain additional control functions which may provide among other things graphic sets outside the standard set. Such control functions must not be used as additional transmission controls.

The use of the character ESC and of the escape sequences in conjunction with code extension techniques is the subject of an ISO Standard.

ETB — *End of transmission block* — A transmission control character used to indicate the end of a transmission block of data where data are divided into such blocks for transmission purposes.

ETX — *End of text* — A transmission control character which terminates a text.

FF — *Form feed* — A format effector which advances the active position to the same character position on a pre-determined line of the next form or page.

HT — *Horizontal tabulation* — A format effector which advances the active position to the next pre-determined character position on the same line.

Information separators

IS_1 (US) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a UNIT.

IS_2 (RS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a RECORD.

IS_3 (GS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a GROUP.

IS_4 (FS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a FILE.

LF — *Line feed* — A format effector which advances the active position to the same character position of the next line.

NAK — *Negative acknowledge* — A transmission control character transmitted by a receiver as a negative response to the sender.

NUL — *Null* — A control character used to accomplish media-fill or time-fill. NUL characters may be inserted into or removed from a stream of data without affecting the information content of that stream, but then the addition or removal of these characters may affect the information layout and/or the control of equipment.

SI — *Shift-in* — A control character which is used in conjunction with SHIFT-OUT and ESCAPE to extend the graphic character set of the code. It may reinstate the standard meanings of the bit combinations which follow it. The effect of this character when using code extension techniques is described in an ISO Standard.

SO — *Shift-out* — A control character which is used in conjunction with SHIFT-IN and ESCAPE to extend the graphic character set of the code. It may alter the meaning of the bit combinations of columns 2 to 7 which follow it until a SHIFT-IN character is reached. However, the characters SPACE (2/0) and DELETE (7/15) are unaffected by SHIFT-OUT. The effect of this character when using code extension techniques is described in an ISO Standard.

SOH — *Start of heading* — A transmission control character used as the first character of a heading of an information message.

SP — *Space* — A character which advances the active position one character position on the same line. This character is also regarded as a non-printing graphic.

STX — *Start of text* — A transmission control character which precedes a text and which is used to terminate a heading.

SUB — *Substitute character* — A control character used in the place of a character that has been found to be invalid or in error. SUB is intended to be introduced by automatic means.

SYN — *Synchronous idle* — A transmission control character used by a synchronous transmission system in the absence of any other character (idle condition) to provide a signal from which synchronism may be achieved or retained between data-terminal equipment.

VT — *Vertical tabulation* — A format effector which advances the active position to the same character position on the next pre-determined line.

b) An information message used for the exchange of data shall take one of the following forms:

```
1) S          E  B
   T---TEXT---T  C
   X          X  C

2) S          E  B
   T---TEXT---T  C
   X          B  C

3) S             S          E  B
   O---HEADING---T---TEXT---T  C
   H             X          X  C

4) S             S          E  B
   O---HEADING---T---TEXT---T  C
   H             X          B  C

5) S             E  B
   O---HEADING---T  C
   H             B  C
```

Note 1.— B C C is a block check character. (BCC)

Note 2.— In formats 2), 4), and 5) above which end with ETB, some continuation is required.

c) A supervisory sequence shall be composed of either a single transmission control character (EOT, ENQ, ACK, or NAK) or a single transmission control (ENQ) preceded by a prefix of up to 15 non-control characters, or the character DLE used in conjunction with other graphic and control characters to provide additional communication control functions.

4.12.3.3 Three system categories are specified in terms of their respective circuit characteristics, terminal configurations, and message transfer procedures as follows:

System category A: two-way alternate, multipoint allowing either centralized or non-centralized operation and single or multiple message-oriented information transfers without replies (but with delivery verification).

System category B: two-way simultaneous, point-to-point employing message associated blocking and modulo 8 numbering of blocks and acknowledgements.

System category C: two-way alternate, multipoint allowing only centralized (computer-to-terminal) operation, single or multiple message transfers with replies.

4.12.3.3.1 In addition to the characteristics prescribed in the paragraphs that follow for both system categories A and B, other parameters that shall be accounted for in order to ensure viable, operationally reliable communications include:

a) the number of SYN characters required to establish and maintain synchronization;

Note.— Normally the transmitting station sends three contiguous SYN characters and the receiving station detects at least two before any action is taken.

b) the values of system time-outs for such functions as "idle line" and "no response" as well as the number of automatic retries that are to be attempted before manual intervention is signalled;

c) the composition of prefixes within a 15 character maximum.

Note.— By agreement between the administrations concerned, it is permissible for supervisory signals to contain a station identification prefix using characters selected from columns 4 through 7 of IA-5.

4.12.3.3.2 **Recommendation.**— *For multipoint implementations designed to permit only centralized (computer-to-terminal) operations, the provisions of Section 4.12.3.7 should be employed.*

4.12.3.4 *Block check character.*

4.12.3.4.1 Both system category A and B shall utilize a block check character to determine the validity of a transmission.

4.12.3.4.2 The block check character shall be composed of 7 bits plus a parity bit.

4.12.3.4.3 Each of the first 7 bits of the block check character shall be the modulo 2 binary sum of every element in the same bit 1 to bit 7 column of the successive characters of the transmitted block.

4.12.3.4.4 The longitudinal parity of each column of the block, including the block check character, shall be even.

4.12.3.4.5 The sense of the parity bit of the block check character shall be the same as for the information characters (see 4.12.1.2.3 above).

4.12.3.4.6 *Summation.*

4.12.3.4.6.1 The summation to obtain the block check character shall be started by the first appearance of either SOH (start of heading) or STX (start of text).

4.12.3.4.6.2 The starting character shall not be included in the summation.

4.12.3.4.6.3 If an STX character appears after the summation has been started by SOH, then the STX character shall be included in the summation as if it were a text character.

4.12.3.4.6.4 With the exception of SYN (synchronous idle), all the characters which are transmitted after the start of the block check summation shall be included in the summation, including the ETB (end of transmission/block) or ETX (end of text) control character which signals that the following character is the block check character.

4.12.3.4.7 No character, SYN or otherwise, shall be inserted between the ETB or ETX character and the block check character.

4.12.3.5 *Description of system category A.* System category A is one in which a number of stations are connected by a multipoint link and one station is permanently designated as the control station which monitors the link at all times to ensure orderly operation.

4.12.3.5.1 *Link establishment procedure*

4.12.3.5.1.1 To establish the link for transmission, the control station shall either:

a) poll one of the tributary stations to assign it master status; or

b) assume master status and select one or more tributary (slave) stations to receive a transmission.

4.12.3.5.1.2 Polling shall be accomplished by the control station sending a polling supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

4.12.3.5.1.3 A tributary station detecting its assigned polling supervisory sequence shall assume master status and respond in one of two ways:

a) if the station has a message to send, it shall initiate a selection supervisory sequence as described in 4.12.3.5.1.5 below;

b) if the station has no message to send, it shall send EOT, and master status shall revert to the control station.

4.12.3.5.1.4 If the control station detects an invalid or no response resulting from a poll, it shall terminate by sending EOT prior to resuming polling or selection.

4.12.3.5.1.5 Selection shall be accomplished by the designated master station sending a selection supervisory sequence consisting of a prefix identifying a single station and ending in ENQ.

4.12.3.5.1.6 A station detecting its assigned selection supervisory sequence shall assume slave status and send one of two replies:

a) if the station is ready to receive, it shall send a prefix followed by ACK. Upon detecting this reply, the master station shall either select another station or proceed with message transfer;

b) if the station is not ready to receive, it shall send a prefix followed by NAK and thereby relinquish slave status. If the master station receives NAK, or no reply, it shall either select another or the same tributary station or terminate;

c) it shall be permissible for N retries ($N \geq 0$) to be made to select a station for which NAK, an invalid reply, or no response has been received.

4.12.3.5.1.7 If one or more stations have been selected and have properly responded with ACK, the master station shall proceed with message transfer.

4.12.3.5.2 *Message transfer procedure*

4.12.3.5.2.1 The master station shall send a message or series of messages, with or without headings to the selected slave station(s).

4.12.3.5.2.2 The transmission of a message shall:

a) begin with:

— SOH if the message has a heading,

— STX if the message has no heading;

b) be continuous, ending with ETX, immediately followed by a block check character (BCC).

4.12.3.5.2.3 After transmitting one or more messages, the master station shall verify successful delivery at each selected slave station.

4.12.3.5.3 *Delivery verification procedure*

4.12.3.5.3.1 The master station shall send a delivery verification supervisory sequence consisting of a prefix identifying a single slave station and ending in ENQ.

4.12.3.5.3.2 A slave station detecting its assigned delivery verification supervisory sequence shall send one of two replies:

a) if the slave station properly received all of the transmission, it shall send an optional prefix followed by ACK;

b) if the slave station did not receive all of the transmission properly, it shall send an optional prefix followed by NAK.

4.12.3.5.3.3 If the master station receives no reply or an invalid reply, it shall request a reply from the same or another slave station until all selected stations have been properly accounted for.

4.12.3.5.3.4 If the master station receives a negative reply (NAK) or, after $N \geq 0$ repeat attempts, no reply, it shall repeat that transmission to the appropriate slave stations at a later opportunity.

4.12.3.5.3.5 After all messages have been sent and delivery verified, the master station shall proceed with link termination.

4.12.3.5.4 *Link termination procedure*

4.12.3.5.4.1 The terminate function, negating the master or slave status of all stations and returning master status to the control station, shall be accomplished by the master station transmitting EOT.

4.12.3.6 *Description of system category B.* System category B is one in which two stations are on a point-to-point, full-duplex link and each station has the capability to maintain concurrent master and slave status, i.e. master status

on its transmit side and slave status on its receive side and both stations can transmit simultaneously.

4.12.3.6.1 *Link establishment procedure*

4.12.3.6.1.1 To establish the link for message transfers (from the calling to the called station), the calling station shall request the identity of the called station by sending an identification supervisory sequence consisting of a DLE character followed by a colon character, an optional prefix, and ENQ.

4.12.3.6.1.2 The called station, upon detecting ENQ, shall send one of two replies:

a) if ready to receive, it shall send a sequence consisting of a DLE followed by a colon, a prefix which includes its identity and ended by ACK0 (see 4.12.3.6.2.5 below). This establishes the link for message transfers from the calling to the called station;

b) if not ready to receive, it shall send the above sequence with the ACK0 replaced by NAK.

4.12.3.6.1.3 Establishment of the link for message transfers in the opposite direction can be initiated at any time following circuit connexion in a similar manner to that described above.

4.12.3.6.2 *Message transfer procedure*

4.12.3.6.2.1 System category B message transfer provides for message associated blocking with longitudinal checking and modulo 8 numbered acknowledgements.

4.12.3.6.2.2 It is permissible for a transmission block to be a complete message or a portion of a message. The sending station shall initiate the transmission with SOTB N followed by:

a) SOH if it is the beginning of a message that contains a heading;

b) STX if it is the beginning of a message that has no heading;

c) SOH if it is an intermediate block that continues a heading;

d) STX if it is an intermediate block that continues a text.

Note.— SOTB N is the two-character transmission control sequence DLE = (characters 1/0, and 3/13) followed by the block number, N, where N is one of the IA-5 characters 0, 1 . . . . 7. (characters 3/0, 3/1 . . . 3/7).

4.12.3.6.2.3 A block which ends at an intermediate point within a message shall be ended with ETB; a block which ends at the end of a message shall be ended with ETX.

4.12.3.6.2.4 It shall be permissible for each station to initiate and continue to send messages to the other concurrently according to the following sequence.

a) It shall be permissible for the sending station (master side) to send blocks, containing messages or parts of messages, continuously to the receiving station (slave side) without waiting for a reply.

b) It shall be permissible for replies, in the form of slave responses, to be transmitted by the receiving station while the sending station is sending subsequent blocks.

Note.— By use of modulo 8 numbering of blocks and replies, it shall be permissible for the sending station to send as many as seven blocks ahead of the received replies before being required to stop transmission until six or less blocks are outstanding.

c) If a negative reply is received, the sending station (master side) shall start retransmission with the block following the last block for which the proper affirmative acknowledgement was received.

4.12.3.6.2.5 Slave responses shall be according to one of the following:

a) if a transmission block is received without error and the station is ready to receive another block, it shall send DLE, a colon, an optional prefix, and the appropriate acknowledgement ACKN (referring to the received block beginning with SOTB N, e.g. ACK0, transmitted as DLE0 is used as the affirmative reply to the block numbered SOTB0, DLE1 for SOTB1, etc.);

b) if a transmission block is not acceptable, the receiving station shall send DLE, a colon, an optional prefix, and NAK.

4.12.3.6.2.6 **Recommendation.—** *Slave responses should be interleaved between message blocks and transmitted at the earliest possible time.*

4.12.3.6.3 *Link termination procedure*

4.12.3.6.3.1 If the link has been established for message transfers in either or both directions, the sending of EOT by a station shall signal the end of message transfers in that direction. To resume message transfers after sending EOT, the link shall be re-established in that direction.

4.12.3.6.3.2 EOT shall only be transmitted by a station after all outstanding slave responses have been received or otherwise accounted for.

4.12.3.6.4 *Circuit disconnexion*

4.12.3.6.4.1 On switched connexions, the data links in both directions shall be terminated before the connexion is cleared. In addition, the station initiating clearing of the connexion shall first announce its intention to do so by transmitting the two-character sequence DLE EOT, followed by any other signals required to clear the connexion.

4.12.3.7 *Description of system category C (centralized).* System category C (centralized) is one (like system category A)

in which a number of stations are connected by a multipoint link and one station is designated as the control station but (unlike system category A) provides only for centralized (computer-to-terminal) operations where message interchange (with replies) shall be constrained to occur only between the control and a selected tributary station.

4.12.3.7.1 *Link establishment procedure*

4.12.3.7.1.1 To establish the link for transmission the control station shall either:

a) poll one of the tributary stations to assign it master status; or

b) assume master status and select a tributary station to assume slave status and receive a transmission according to either of two prescribed selection procedures:

1) selection with response (see 4.12.3.7.1.5 below); or

2) fast select (see 4.12.3.7.1.7 below).

4.12.3.7.1.2 Polling is accomplished by the control station sending a polling supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

4.12.3.7.1.3 A tributary station detecting its assigned polling supervisory sequence shall assume master status and respond in one of two ways:

a) if the station has a message to send, it shall initiate message transfer. The control station assumes slave status;

b) if the station has no message to send, it shall send EOT and master status shall revert to the control station.

4.12.3.7.1.4 If the control station detects an invalid or no response resulting from a poll, it shall terminate by sending EOT prior to resuming polling or selection.

4.12.3.7.1.5 Selection with response is accomplished by the control station assuming master status and sending a selection supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

4.12.3.7.1.6 A tributary station detecting its assigned selection supervisory sequence shall assume slave status and send one of two replies:

a) if the station is ready to receive, it shall send an optional prefix followed by ACK. Upon detecting this reply, the master station shall proceed with message transfer;

b) if the station is not ready to receive, it shall send an optional prefix followed by NAK. Upon detecting NAK, it shall be permissible for the master station to again attempt selecting the same tributary station or initiate termination by sending EOT.

Note.— If the control station receives an invalid or no reply, it is permitted to attempt again to select the same tributary or after N retries (N ⩾ 0) either to exit to a recovery procedure or to initiate termination by sending EOT.

4.12.3.7.1.7 Fast select is accomplished by the control station assuming master status and sending a selection supervisory sequence, and without ending this transmission with ENQ or waiting for the selected tributary to respond, proceeding directly to message transfer.

4.12.3.7.2 *Message transfer procedure*

4.12.3.7.2.1 The station with master status shall send a single message to the station with slave status and wait for a reply.

4.12.3.7.2.2 The message transmission shall:

a) begin with:

— SOH if the message has a heading,

— STX if the message has no heading;

and

b) be continuous, ending with ETX, immediately followed by BCC.

4.12.3.7.2.3 The slave station, upon detecting ETX followed by BCC, shall send one of two replies:

a) if the messages were accepted and the slave station is ready to receive another message, it shall send an optional prefix followed by ACK. Upon detecting ACK, the master station shall be permitted either to transmit the next message or initiate termination;

b) if the message was not accepted and the slave station is ready to receive another message, it shall send an optional prefix followed by NAK. Upon detecting NAK, the master station may either transmit another message or initiate termination. Following the NAK reply, the next message transmitted need not be a retransmission of the message that was not accepted.

4.12.3.7.2.4 If the master station receives an invalid or no reply to a message, it shall be permitted to send a delivery verification supervisory sequence consisting of an optional prefix followed by ENQ. Upon receipt of a delivery verification supervisory sequence, the slave station repeats its last reply.

4.12.3.7.2.5 N retries (N ⩾ 0) may be made by the master station in order to get a valid slave reply. If a valid reply is not received after N retries, the master station exits to a recovery procedure.

4.12.3.7.3 *Link termination procedure*

4.12.3.7.3.1 The station with master status shall transmit EOT to indicate that it has no more messages to transmit.

EOT shall negate the master/slave status of both stations and return master status to the control station.

4.12.4 Ground-ground bit-oriented data link control procedures

Note.— The provisions of this section pertain to ground-ground data interchange applications using bit-oriented data link control procedures enabling transparent, synchronous transmission that is independent of any encoding; data link control functions are accomplished by interpreting designated bit positions in the transmission envelope of a frame.

4.12.4.1 The following descriptions shall apply to data link applications contained in this section.

a) Bit-oriented data link control procedures enable transparent transmission that is independent of any encoding.

b) A data link is the logical association of two interconnected stations, including the communication control capability of the interconnected stations.

c) A station is a configuration of logical elements, from or to which messages are transmitted on a data link, including those elements which control the message flow on the link via communication control procedures.

d) A combined station sends and receives both commands and responses and is responsible for control of the data link.

e) Data communication control procedures are the means used to control and protect the orderly interchange of information between stations on a data link.

f) A component is defined as a number of bits in a prescribed order within a sequence for the control and supervision of the data link.

g) An octet is a group of 8 consecutive bits.

h) A sequence is one or more components in prescribed order comprising an integral number of octets.

i) A field is a series of a specified number of bits or specified maximum number of bits which performs the functions of data link or communications control or constitutes data to be transferred.

j) A frame is a unit of data to be transferred over the data link, comprising one or more fields in a prescribed order.

k) A common ICAO data interchange network (CIDIN) switching centre is that part of an automatic AFTN switching centre which provides for the entry, relay, and exit centre functions using the bit-oriented link and CIDIN network procedures specified in this section and includes the appropriate interface(s) with other parts of the AFTN and with other networks.

4.12.4.2 *Bit-oriented data link control procedures for point-to-point, ground-ground data interchange applications employing synchronous transmission facilities*

Note.— The following link level procedures are the same as the LAPB link level procedures described in ITU CCITT Recommendation X.25, Section 2, Yellow Book (1981 version).

4.12.4.2.1 *Frame format.* Frames shall contain not less than 32 bits, excluding the opening and closing flags, and shall conform to the following format:

FLAG F	ADDRESS A	CONTROL C	INFORMATION I	FCS	FLAG F

4.12.4.2.1.1 A frame shall consist of an opening flag (F), an address field (A), a control field (C), an optional information field (I), a frame check sequence (FCS), and a closing flag sequence (F), and shall be transmitted in that order.

Note.— In relation to CIDIN, the opening flag, the fields A and C, the FCS and the closing flag form together the Data Link Control Field (DLCF). The field I is denoted as the Link Data Field (LDF).

4.12.4.2.1.1.1 The flag (F) shall be the 8-bit sequence 01111110 which delimits the beginning and ending of each frame. It shall be permissible for the closing flag of a frame to also serve as the opening flag of the next frame.

4.12.4.2.1.1.2 The address (A) field shall consist of one octet, excluding 0 bits added to achieve transparent transmission, which shall contain the link address of the combined station.

4.12.4.2.1.1.3 The control (C) field shall consist of one octet, excluding 0 bits added to achieve transparent transmission, and shall contain the commands, responses, and frame sequence number components for the control of the data link.

4.12.4.2.1.1.4 The information (I) field shall contain digital data which may be presented in any code or sequence but shall not exceed a maximum of 259 octets, excluding 0 bits added to achieve transparent transmission. The I field shall always be a multiple of 8 bits in length.

4.12.4.2.1.1.5 The frame check sequence (FCS) shall consist of two octets, excluding 0 bits added to achieve transparent transmission, and shall contain the error detecting bits.

4.12.4.2.2 A frame check sequence (FCS) shall be included in each frame for the purpose of error checking.

4.12.4.2.2.1 The error checking algorithm shall be a cyclic redundancy check (CRC).

4.12.4.2.2.2 The CRC polynominal (P(x)) shall be

$$x^{16} + x^{12} + x^5 + 1.$$

4.12.4.2.2.3 The FCS shall be a 16-bit sequence. This FCS shall be the ones' complement of the remainder, R(x), obtained from the modulo 2 division of

$$x^{16}[G(x)] + x^{K}(x^{15} + x^{14} + x^{13} + \ldots + x^{2} + x^{1} + 1)$$

by the CRC polynomial, P(x).

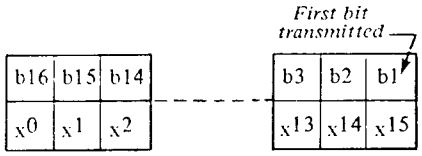
G(x) shall be the contents of the frame existing between, but including neither, the final bit of the opening flag nor the first bit of the FCS, excluding bits inserted for transparent transmission.

K shall be the length of G(x) (number of bits).

4.12.4.2.2.4 The generation and checking of the FCS accumulation shall be as follows:

a) the transmitting station shall initiate the FCS accumulation with the first (least significant) bit of the address (A) field and shall include all bits up to and including the last bit preceding the FCS sequence, but shall exclude all 0 bits (if any) inserted to achieve transparent transmission;

b) upon completion of the accumulation the FCS shall be transmitted, starting with bit b1 (highest order coefficient) and proceeding in sequence to bit b16 (lowest order coefficient) as shown below;



c) the receiving station shall carry out the cyclic redundancy check (CRC) on the content of the frame commencing with the first bit received following the opening flag, and shall include all bits up to and including the last bit preceding the closing flag, but shall exclude all 0 bits (if any) deleted according to the rules for achievement of transparency;

d) upon completion of the FCS accumulation, the receiving station shall examine the remainder. In the absence of transmission error, the remainder shall be 1111000010111000 (x^0 through x^{15}, respectively).

4.12.4.2.3 *Achievement of transparency.* The frame format contents (A, C, link data field, and FCS) shall be capable of containing any bit configuration.

4.12.4.2.3.1 The following rules shall apply to all frame contents, except flag sequences:

a) the transmitting station shall examine the frame contents before transmission, and shall insert a single 0 bit immediately following each sequence of 5 consecutive 1 bits;

b) the receiving station shall examine the received frame contents for patterns consisting of 5 consecutive 1 bits immediately followed by one (or more) 0 bit(s) and shall remove the 0 bit which directly follows 5 consecutive 1 bits.

4.12.4.2.4 *Special transmission sequences and related link states.* In addition to employing the prescribed repertoire of commands and responses to manage the interchange of data and control information, stations shall use the following conventions to signal the indicated conditions:

a) *Abort* is the procedure by which a station in the process of sending a frame ends the frame in an unusual manner such that the receiving station shall ignore the frame. The conventions for aborting a frame shall be:

1) transmitting at least seven, but less than fifteen, one bits (with no inserted zeros);

2) receiving seven one bits.

b) *Active link state.* A link is in an active state when a station is transmitting a frame, an abort sequence, or interframe time fill. When the link is in the active state, the right of the transmitting station to continue transmission shall be reserved.

c) *Interframe time fill.* Interframe time fill shall be accomplished by transmitting continuous flags between frames. There is no provision for time fill within a frame.

d) *Idle link state.* A link is in an idle state when a continuous one condition is detected that persists for 15 bit times, or longer. Idle link time fill shall be a continuous one condition on the link.

e) *Invalid frame.* An invalid frame is one that is not properly bounded by two flags or one which is shorter than 32 bits between flags.

4.12.4.2.5 *Modes*

4.12.4.2.5.1 *Operational mode.* The operational mode shall be the asynchronous balanced mode (ABM).

4.12.4.2.5.1.1 It shall be permissible for a combined station in ABM to transmit without invitation from the associated station.

4.12.4.2.5.1.2 A combined station in ABM shall be permitted to transmit any command or response type frame except DM.

4.12.4.2.5.2 *Non-operational mode.* The non-operational mode shall be the asynchronous disconnected mode (ADM) in which a combined station is logically disconnected from the data link.

4.12.4.2.5.2.1 It shall be permissible for a combined station in ADM to transmit without invitation from the associated station.

4.12.4.2.5.2.2 A combined station in ADM shall transmit only SABM, DISC, UA and DM frames. (See 4.12.4.2.7

Table 4-5. Control field formats

Control Field Format for	Control Field Bits							
	1	2	3	4	5	6	7	8
Information Transfer (I Frame)	0	N(S)			P	N(R)		
Supervisory Commands/Responses (S Frame)	1	0	S	S	P/F	N(R)		
Unnumbered Commands/Responses	1	1	M	M	P/F	M	M	M

Where: N(S) = Send sequence count (Bit 2 = low order bit)
N(R) = Receive sequence count (Bit 6 = low order bit)
S = Supervisory function bits
M = Modifier function bits
P = Poll bit (in commands)
F = Final bit (in responses)

below for a description of the commands and responses to which these frame types refer.)

4.12.4.2.5.2.3 A combined station in ADM shall transmit a DM when a DISC is received, and shall discard all other received command frames except SABM. If a discarded command frame has the P bit set to "1", the combined station shall transmit a DM with the F bit set to "1".

4.12.4.2.6 *Control field functions and parameters.* Control fields contain a command or a response and sequence numbers where applicable. Three types of control fields shall be used to perform:

a) numbered information transfer (I-frames);

b) numbered supervisory functions (S-frames); and

c) unnumbered control functions (U-frames).

The control field formats shall be as shown in Table 4-5. The functional frame designation associated with each type control field as well as the control field parameters employed in performing these functions shall be described in the following paragraphs.

4.12.4.2.6.1 The I-frame type is used to perform information transfers. Except for some special cases it is the only format which shall be permitted to contain an information field.

4.12.4.2.6.2 The S-frame type is used for supervisory commands and responses that perform link supervisory control functions such as acknowledge information frames, request transmission or retransmission of information frames, and to request a temporary suspension of transmission of I-frames. No information field shall be contained in the S-frame.

4.12.4.2.6.3 The U-frame type is used for unnumbered commands and responses that provide additional link control functions. One of the U-frame responses, the frame reject (FRMR) response, shall contain an information field; all other frames of the U-frame type shall not contain an information field.

4.12.4.2.6.4 The station parameters associated with the three control field types shall be as follows:

a) *Modulus.* Each I-frame shall be sequentially numbered with a send sequence count, N(S), having value 0 through modulus minus one (where modulus is the modulus of the sequence numbers). The modulus shall be 8. The maximum number of sequentially numbered I-frames that a station shall have outstanding (i.e. unacknowledged) at any given time shall never exceed one less than the modulus of the sequence numbers. This restriction on the number of outstanding frames is to prevent any ambiguity in the association of transmission frames with sequence numbers during normal operation and/or error recovery.

b) The send state variable V(S) shall denote the sequence number of the next in-sequence I-frame to be transmitted.

   1) The send state variable shall take on the value 0 through modulus minus one (modulus is the modulus of the sequence numbering and the numbers cycle through the entire range).

   2) The value of V(S) shall be incremented by one with each successive in-sequence I-frame transmission, but shall not exceed the value of N(R) contained in the last received frame by more than the maximum permissible number of outstanding I-frames (k). See i) below for the definition of k.

c) Prior to transmission of an in-sequence I-frame, the value of N(S) shall be updated to equal the value of V(S).

d) The receive state variable V(R) shall denote the sequence number of the next in-sequence I-frame to be received.

1) V(R) shall take on the values 0 through modulus minus one.

2) The value of V(R) shall be incremented by one after the receipt of an error-free, in-sequence I-frame whose send sequence number N(S), equals V(R).

e) All I-frames and S-frames shall contain N(R), the expected sequence number of the next received frame. Prior to transmission of either an I or an S type frame, the value of N(R) shall be updated to equal the current value of the receive state variable. N(R) indicates that the station transmitting the N(R) has correctly received all I-frames numbered up to and including N(R) - 1.

f) Each station shall maintain an independent send state variable, V(S), and receive state variable, V(R), on the I-frames it sends and receives. That is, each combined station shall maintain a V(S) count on the I-frames it transmits and a V(R) count on the I-frames it has correctly received from the remote combined station.

g) The poll (P/F) bit shall be used by a combined station to solicit (poll) a response or sequence of responses from the remote combined station.

h) The final (P/F) bit shall be used by the remote combined station to indicate the response frame transmitted as the result of a soliciting (poll) command.

i) The maximum number (k) of sequentially numbered I-frames that a station may have outstanding (i.e. unacknowledged) at any given time is a station parameter which shall never exceed the modulus.

Note.— k is determined by station buffering limitations and should be the subject of bilateral agreement at the time of circuit establishment.

4.12.4.2.7 *Commands and responses.* It shall be permissible for a combined station to generate either commands or responses. A command shall contain the remote station address while a response shall contain the sending station address. The mnemonics associated with all of the commands and responses prescribed for each of the three frame types (I, S, and U) and the corresponding encoding of the control field are as shown in Table 4-6.

4.12.4.2.7.1 The I-frame command provides the means for transmitting sequentially numbered frames, each of which shall be permitted to contain an information field.

4.12.4.2.7.2 The S-frame commands and responses shall be used to perform numbered supervisory functions (such as acknowledgement, polling, temporary suspension of information transfer, or error recovery).

4.12.4.2.7.2.1 The receive ready command or response (RR) shall be used by a station to:

a) indicate that it is ready to receive an I-frame;

b) acknowledge previously received I-frames numbered up to and including N(R) - 1;

c) clear a busy condition that was initiated by the transmission of RNR.

Note.— It is permissible for a combined station to use the RR command to solicit a response from the remote combined station with the poll bit set to "1".

4.12.4.2.7.2:2 It shall be permissible to issue a reject command or response (REJ) to request retransmission of frames starting with the I-frame numbered N(R) where:

Table 4-6. Commands and responses

Type	*Commands*		*Responses*		*C field encoding* 1	2	3	4	5	6	7	8
Information transfer	I	(information)			0	N(S)			P	N(R)		
Supervisory	RR	(receive ready)	RR	(receive ready)	1	0	0	0	P/F	N(R)		
	RNR	(receive not ready)	RNR	(receive not ready)	1	0	1	0	P/F	N(R)		
	REJ	(reject)	REJ	(reject)	1	0	0	1	P/F	N(R)		
Unnumbered			DM	(disconnected mode)	1	1	1	1	P/F	0	0	0
	SABM	(set asynchronous balanced mode)			1	1	1	1	P	1	0	0
	DISC	(disconnect)			1	1	0	0	P	0	1	0
			UA	(unnumbered acknowledgement)	1	1	0	0	F	1	1	0
			FRMR	(frame reject)	1	1	1	0	F	0	0	1

a) I-frames numbered N(R) - 1 and below are acknowledged;

b) additional I-frames pending initial transmission are to be transmitted following the retransmitted I-frame(s);

c) only one REJ exception condition, from one given station to another station, shall be established at any given time: another REJ shall not be issued until the first REJ exception condition has been cleared;

d) the REJ exception condition is cleared (reset) upon the receipt of an I-frame with an N(S) count equal to the N(R) of the REJ command/response.

4.12.4.2.7.2.3 The receive not ready command or response (RNR) shall be used to indicate a busy condition, i.e. temporary inability to accept additional incoming I-frames, where:

a) frames numbered up to and including N(R) - 1 are acknowledged;

b) frame N(R) and any subsequent I-frames received, if any, are not acknowledged (the acceptance status of these frames shall be indicated in subsequent exchanges);

c) the clearing of a busy condition shall be indicated by the transmission of an RR, REJ, SABM, or UA with or without the P/F bit set to "1".

4.12.4.2.7.2.3.1 **Recommendation.—**

a) A station receiving an RNR frame when in the process of transmitting should stop transmitting I-frames at the earliest possible time.

b) Any REJ command or response which was received prior to the RNR should be actioned before the termination of transmission.

c) It should be permissible for a combined station to use the RNR command with the poll bit set to "1" to obtain a supervisory frame with the final bit set to "1" from the remote combined station.

4.12.4.2.7.2.4 It shall be permissible for the selective reject command or response (SREJ) to be used to request retransmission of the single I-frame numbered N(R) where:

a) frames numbered up to N(R) - 1 are acknowledged; frame N(R) is not accepted; the only I-frames accepted are those received correctly and in sequence following the I-frame requested; the specific I-frame to be retransmitted is indicated by the N(R) in the SREJ command/response;

b) the SREJ exception condition is cleared (reset) upon receipt of an I-frame with an N(S) count equal to the N(R) of the SREJ;

c) after a station transmits a SREJ it is not permitted to transmit SREJ or REJ for an additional sequence error until the first SREJ error condition has been cleared;

d) I-frames that have been permitted to be transmitted following the I-frame indicated by the SREJ are not retransmitted as the result of receiving a SREJ; and

e) it is permissible for additional I-frames pending initial transmission to be transmitted following the retransmission of the specific I-frame requested by the SREJ.

4.12.4.2.7.3 The U-frame commands and responses shall be used to extend the number of link control functions. Transmitted U-frames do not increment the sequence counts at either the transmitting or receiving station.

a) The U-frame mode-setting commands (SABM, and DISC) shall be used to place the addressed station in the appropriate response mode (ABM or ADM) where:

1) upon acceptance of the command, the station send and receive state variables, V(S) and V(R), are set to zero;

2) the addressed station confirms acceptance at the earliest possible time by transmission of a single unnumbered acknowledgement, UA;

3) previously transmitted frames that are unacknowledged when the command is actioned remain unacknowledged;

4) the DISC command is used to perform a logical disconnect, i.e. to inform the addressed combined station that the transmitting combined station is suspending operation. No information field shall be permitted with the DISC command.

b) The unnumbered acknowledge response (UA) shall be used by a combined station to acknowledge the receipt and acceptance of an unnumbered command. Received unnumbered commands are not actioned until the UA response is transmitted. No information field shall be permitted with the UA response.

c) The frame reject response (FRMR), employing the information field described below, shall be used by a combined station in the operational mode (ABM) to report that one of the following conditions resulted from the receipt of a frame without an FCS error:

1) a command/response that is invalid or not implemented;

2) a frame with an information field that exceeds the size of the buffer available;

3) a frame having an invalid N(R) count.

Note.— An invalid N(R) is a count which points to an I-frame which has previously been transmitted and *acknowledged or to an I-frame which has not been transmitted* and *is not the next sequential I-frame pending transmission.*

FRMR INFORMATION FIELD BITS FOR BASIC (SABM) OPERATION

First bit transmitted

1 — 8	9	10 — 12	13	14 — 16	17	18	19	20	21 — 24
rejected basic control field	0	V(S)	v	V(R)	w	x	y	z	set to zero

where:

rejected basic control field is the control field of the received frame which caused the frame reject;

V(S) is the current value of the send state variable at the remote combined station reporting the error condition (Bit 10 = low order bit);

V(R) is the current value of the receive state variable at the remote combined station reporting the error condition (Bit 14 = low order bit);

v set to "1" indicates that the received frame which caused rejection was a response;

w set to "1" indicates that the control field received and returned in bits 1 through 8 are invalid or not implemented;

x set to "1" indicates that the control field received and returned in bits 1 through 8 was considered invalid because the frame contained an information field which is not permitted with this command. Bit w must be set to "1" in conjunction with this bit;

y set to "1" indicates that the information field received exceeded the maximum information field length which can be accommodated by the station reporting the error condition. This bit is mutually exclusive with bits w and x above;

z set to "1" indicates that the control field received and returned in bits 1 through 8 contained an invalid N(R) count. This bit is mutually exclusive with bit w.

d) The disconnected mode response (DM) shall be used to report a non-operational status where the station is logically disconnected from the link. No information field shall be permitted with the DM response.

Note.— The DM response shall be sent to request the remote combined station to issue a mode-setting command or, if sent in response to the reception of a mode-setting command, to inform the remote combined station that the transmitting station is still in ADM and cannot action the mode-setting command.

4.12.4.3 *Exception condition reporting and recovery.* This section specifies the procedures that shall be employed to effect recovery following the detection or occurrence of an exception condition at the link level. Exception conditions described are those situations that may occur as the result of transmission errors, station malfunction, or operational situations.

4.12.4.3.1 *Busy condition.* A busy condition occurs when a station temporarily cannot receive or continue to receive I-frames due to internal constraints, e.g. due to buffering limitations. The busy condition shall be reported to the remote combined station by the transmission of an RNR frame with the N(R) number of the next I-frame that is expected. It shall be permissible for traffic pending transmission at the busy station to be transmitted prior to or following the RNR.

Note.— The continued existence of a busy condition must be reported by retransmission of RNR at each P/F frame exchange.

4.12.4.3.1.1 Upon receipt of an RNR, a combined station in ABM shall cease transmitting I-frames at the earliest possible time by completing or aborting the frame in process. The combined station receiving an RNR shall perform a time-out operation before resuming asynchronous transmission of I-frames unless the busy condition is reported as cleared by the remote combined station. If the RNR was received as a command with the P bit set to "1", the receiving station shall respond with an S-frame with the F bit set to "1".

4.12.4.3.1.2 The busy condition shall be cleared at the station which transmitted the RNR when the internal constraint ceases. Clearance of the busy condition shall be

reported to the remote station by transmission of an RR, REJ, SABM, or UA frame (with or without the P/F bit set to "1").

4.12.4.3.2 *N(S) sequence error.* An N(S) sequence exception shall be established in the receiving station when an I-frame that is received error free (no FCS error) contains an N(S) sequence number that is not equal to the receive variable V(R) at the receiving station. The receiving station shall not acknowledge (shall not increment its receive variable V(R)) the frame causing the sequence error, or any I-frames which may follow, until an I-frame with the correct N(S) number is received. A station that receives one or more I-frames having sequence errors, but which are otherwise error free, shall accept the control information contained in the N(R) field and the P/F bit to perform link control functions, e.g. to receive acknowledgement of previously transmitted I-frames (via the N(R)), to cause the station to respond (P bit set to "1").

4.12.4.3.2.1 The means specified in 4.12.4.3.2.1.1 and 4.12.4.3.2.1.2 below shall be available for initiating the retransmission of lost or errored I-frames following the occurrence of a sequence error.

4.12.4.3.2.1.1 Where the REJ command/response is used to initiate an exception recovery following the detection of a sequence error, only one 'sent REJ' exception condition, from one station to another station, shall be established at a time. A 'sent REJ' exception shall be cleared when the requested I-frame is received. A station receiving REJ shall initiate sequential (re)transmission of I-frames starting with the I-frame indicated by the N(R) contained in the REJ frame.

4.12.4.3.2.1.2 In the event a receiving station, due to a transmission error, does not receive (or receives and discards) a single I-frame or the last I-frame(s) in a sequence of I-frames, it shall not detect an out-of-sequence exception and, therefore, shall not transmit REJ. The station which transmitted the unacknowledged I-frame(s) shall, following the completion of a system-specified time-out period, take appropriate recovery action to determine the sequence number at which retransmission must begin.

4.12.4.3.2.1.3 **Recommendation.**— *A combined station which has timed out waiting for a response should not retransmit all unacknowledged frames immediately. The station may enquire about status with a supervisory frame.*

Note 1.— If a station does retransmit all unacknowledged I-frames after a time-out, it must be prepared to receive a subsequent REJ frame with an N(R) greater than its send variable V(S).

Note 2.— Since contention may occur in the case of two-way alternate communications in ABM or ADM, the time-out interval employed by one combined station must be greater than that employed by the other combined station so as to permit contention to be resolved.

4.12.4.3.3 *FCS error.* Any frame with an FCS error shall not be accepted by the receiving station and will be discarded. No action shall be taken by the receiving station as the result of that frame.

4.12.4.3.4 *Frame reject exception condition.* A frame reject exception condition shall be established upon the receipt of an error-free frame which contains an invalid or unimplemented control field, an invalid N(R), or an information field which has exceeded the maximum established storage capability. If a frame reject exception condition occurs in a combined station, the station shall either:

a) take recovery action without reporting the condition to the remote combined station; or

b) report the condition to the remote combined station with a FRMR response. The remote station will then be expected to take recovery action; if, after waiting an appropriate time, no recovery action appears to have been taken, the combined station reporting the frame reject exception condition may take recovery action.

Recovery action for balanced operation includes the transmission of an implemented mode-setting command. Higher level functions may also be involved in the recovery.

4.12.4.3.5 *Mode-setting contention.* A mode-setting contention situation exists when a combined station issues a mode-setting command and, before receiving an appropriate response (UA or DM), receives a mode-setting command from the remote combined station. Contention situations shall be resolved in the following manner:

a) when the send and receive mode-setting commands are the same, each combined station shall send a UA response at the earliest respond opportunity. Each combined station shall either enter the indicated mode immediately or defer entering the indicated mode until receiving a UA response. In the latter case, if the UA response is not received:

   1) the mode may be entered when the response timer expires; or

   2) the mode-setting command may be reissued;

b) when the mode-setting commands are different, each combined station shall enter ADM and issue a DM response at the earliest respond opportunity. In the case of DISC contention with a different mode-setting command, no further action is required.

4.12.4.3.6 *Time-out functions.* Time-out functions shall be used to detect that a required or expected acknowledging action or response to a previously transmitted frame has not been received. Expiration of the time-out function shall initiate appropriate action, e.g. error recovery or reissuance of the P bit. The duration of the following time-out functions is system dependent and subject to bilateral agreement:

a) combined stations shall provide a time-out function to determine that a response frame with F bit set to "1" to a command frame with the P bit set to "1" has not been received. The time-out function shall automatically cease upon receipt of a valid frame with the F bit set to "1";

b) a combined station which has no P bit outstanding, and which has transmitted one or more frames for which responses are anticipated shall start a time-out function to detect the no-response condition. The time-out function shall cease when an I- or S-frame is received with the N(R) higher than the last received N(R) (actually acknowledging one or more I-frames).

4.12.5 Common ICAO data interchange network (CIDIN)

Note.— The common ICAO data interchange network (CIDIN) is that part of the aeronautical fixed service which uses bit-oriented procedures and packet switching techniques.

4.12.5.1 *CIDIN protocol levels*

4.12.5.1.1 There shall be four protocol levels defined to control the transfer of messages between CIDIN switching centres:

— the data link protocol level

— the X.25 packet protocol level

— the CIDIN packet protocol level

— the transport protocol level

Note.— The relationship of the terms used is shown in Figures 4-3 and 4-4.

4.12.5.1.2 *The data link protocol level*

4.12.5.1.2.1 X.25 packets to be transferred between two CIDIN switching centres or a CIDIN switching centre and a PDN, shall be formatted into data link frames.

4.12.5.1.2.2 Each data link frame shall consist of a data link control field (DLCF), possibly followed by a link data field, and shall be terminated by a frame check sequence and flag (being the second part of the DLCF). If a link data field is present, the frame shall be denoted as an information frame.

4.12.5.1.2.3 X.25 packets shall be transmitted within the link data field of information frames. Only one packet shall be contained in the link data field.

4.12.5.1.2.4 The data link protocol shall be as described in 4.12.4 above.

4.12.5.1.3 *The X.25 packet protocol level (permanent virtual circuit procedure)*

4.12.5.1.3.1 Each CIDIN packet to be transferred on CIDIN circuits between CIDIN switching centres shall be formatted into one X.25 packet. When PDN circuits are used, it shall be permissible to format the CIDIN packet into more than one X.25 packet.

4.12.5.1.3.2 The integrity of each CIDIN packet shall be preserved by the X.25 packet protocol by mapping each CIDIN packet onto one complete X.25 packet sequence, as defined in CCITT Recommendation X.25 (1981).

4.12.5.1.3.3 Each X.25 packet shall consist of an X.25 packet header, possibly followed by a user data field (UDF).

4.12.5.1.3.4 The X.25 packet protocol is based on the application of permanent virtual circuit (PVC) procedures. A permanent virtual circuit shall be defined as a logical path between two CIDIN switching centres. If a public packet switched data network is used to interconnect two CIDIN switching centres, the procedure shall provide full compatibility with the procedures to be followed for PVCs according to CCITT Recommendation X.25 (1981).

4.12.5.1.3.5 The X.25 packet procedures shall be as described in 4.12.6.2 below.

4.12.5.1.4 *The CIDIN packet protocol level*

4.12.5.1.4.1 Each transport header and the associated segment shall be preceded by a CIDIN packet header. No further segmentation of the CIDIN message shall be used between transport protocol level and CIDIN packet protocol level. Both headers, therefore, shall be used in combination. Together they shall be referred to as the Communications Control Field (CCF). Together with the message segment they form CIDIN packets that shall be transmitted from entry centre to exit centre(s), when necessary through one or more relay centres, as an entity.

4.12.5.1.4.2 CIDIN packets of one CIDIN message shall be relayed independently via predetermined routes through the network thus allowing alternative routing on a CIDIN packet basis as necessary.

4.12.5.1.4.3 The CIDIN packet header shall contain information to enable relay centres to handle CIDIN packets in the order of priority, to transmit the CIDIN packets on the proper outgoing circuit(s) and to duplicate or multiplicate CIDIN packets when required for multiple dissemination purposes. The information shall be sufficient to apply address stripping on the exit addresses as well as on the addressee indicators of messages in AFTN format.

Note.— Guidance material on address stripping in the CIDIN is contained in the Manual on the Planning and Engineering of the Aeronautical Fixed Telecommunication Network *(Doc 8259).*

4.12.5.1.4.4 The CIDIN packet procedures shall be as described in 4.12.6.3 below.

4.12.5.1.5 *The transport protocol level*

4.12.5.1.5.1 Information exchanged over the CIDIN shall be transmitted as CIDIN messages.

4.12.5.1.5.2 The length of a CIDIN message shall be defined by the CIDIN packet sequence number (CPSN). The maximum permissible length is 2^{119} packets which in effect results in no practical limitation.

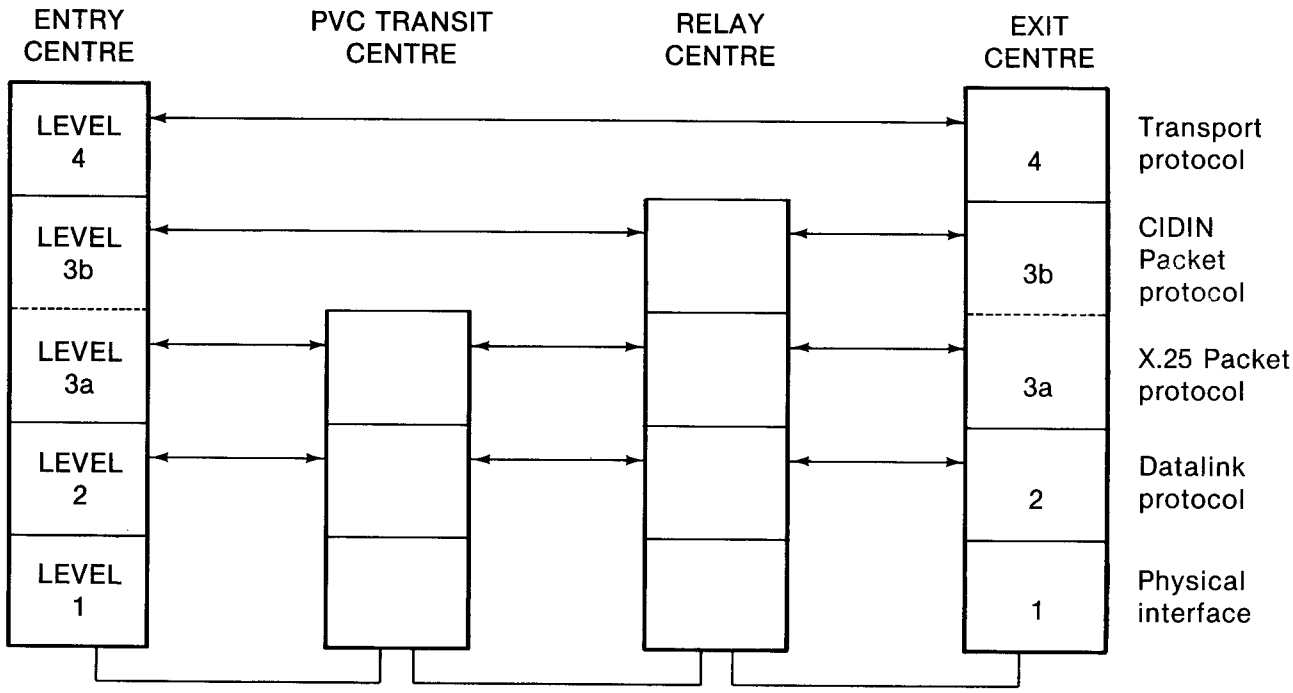


Figure 4-3.— CIDIN Protocol Levels

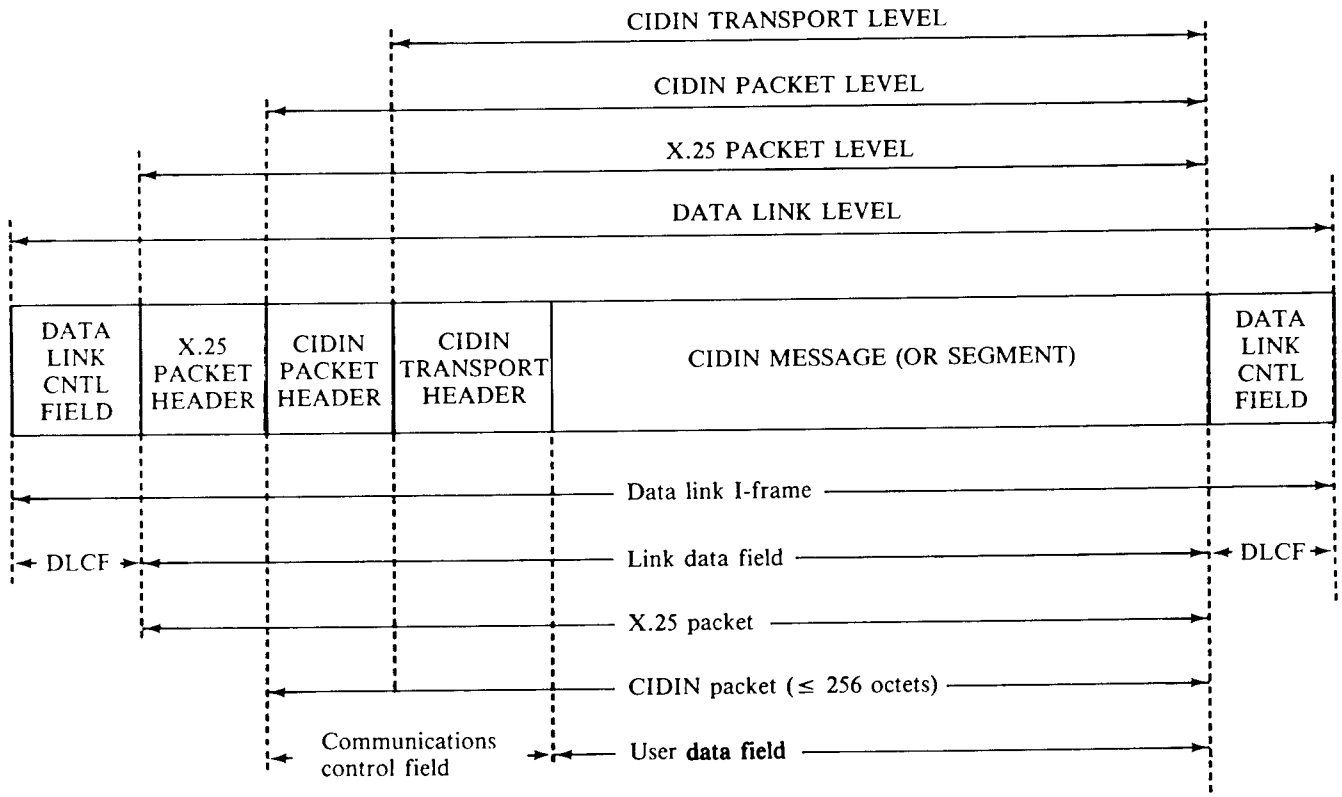


Figure 4-4.— CIDIN Terminology

4.12.5.1.5.3 If the length of a CIDIN message and its transport and packet headers (as defined below) exceeds 256 octets the message shall be divided into segments and placed in the user data field of CIDIN packets. Each segment shall be preceded by a transport header containing information to enable the re-assembly of the CIDIN message at the exit centre(s) from individually received segments and to determine further handling of the received complete CIDIN message.

4.12.5.1.5.4 All segments of one CIDIN message shall be provided with the same message identification information in the transport header. Only the CPSN and final CIDIN packet (FCP) indicator shall be different.

4.12.5.1.5.5 Recovery of messages shall be performed at the transport level.

4.12.5.1.5.6 **Recommendation.—** *When an entry centre has to make separate transmissions of the same message to more than one exit centre, the same message identification number (MIN) should be used for each transmission.*

4.12.5.1.5.7 The transport protocol shall be as described in 4.12.6.4 below.

4.12.6 CIDIN procedures

4.12.6.1 *The data link procedures*

4.12.6.1.1 The data link procedures shall be as described in 4.12.4 above.

4.12.6.2 *The X.25 packet procedures for permanent virtual circuits*

4.12.6.2.1 The following descriptions shall apply to the packet level procedures for permanent virtual circuits.

a) A permanent virtual circuit (PVC) is a logical path which conveys data solely from one PVC termination centre, optionally through PVC transit centres to a single distant PVC termination centre via an assigned logical channel on each of one or more data links.

b) A PVC termination centre is a centre which introduces data into, and receives data from, a PVC.

c) A PVC transit centre is a centre which relays data for a PVC from one assigned logical channel on one data link to another assigned logical channel on another data link.

d) For each PVC within a PVC transit centre, the logical channel assigned to that PVC on one data link can be viewed as the corresponding logical channel with respect to the logical channel assigned to that PVC on another data link.

e) An octet is a group of 8 consecutive bits.

f) In the over-all centre architecture, packet level procedures are considered to exist above the link procedures and below the transport level procedures.

4.12.6.2.2 *Packet format*

4.12.6.2.2.1 The packet format used shall be one of the following:

4.12.6.2.2.1.1 Data packet, comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier, including the packet receive sequence number P(R), the packet send sequence number P(S), and the more data bit M;

d) the user data field, comprising up to 256 octets and ending on an integral octet boundary.

Note.— Public data networks operating in the packet mode and connected with CIDIN using procedures described in ITU CCITT Recommendation X.25-1981 may limit the user data field to not more than 128 octets.

4.12.6.2.2.1.2 RECEIVE READY packet (RR), comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier, including P(R).

4.12.6.2.2.1.3 RECEIVE NOT READY packet (RNR), comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier, including P(R).

4.12.6.2.2.1.4 RESET REQUEST packet, comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier;

d) the resetting cause field (see 4.12.6.2.11 below);

e) the diagnostic code (see 4.12.6.2.10 below).

4.12.6.2.2.1.5 RESET CONFIRMATION packet, comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier.

4.12.6.2.2.1.6 RESTART REQUEST packet, comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier;

d) the restarting cause field;

e) the diagnostic code (see 4.12.6.2.10 below).

4.12.6.2.2.1.7 RESTART CONFIRMATION packet, comprising:

a) the general format identifier;

b) the logical channel identifier, comprising a logical channel group number and a logical channel number;

c) the packet type identifier.

4.12.6.2.2.2 Each packet shall be completely contained in the link data field of a frame.

4.12.6.2.2.3 Only one packet shall be contained in the link data field of a frame.

4.12.6.2.2.4 The octets of each packet shall be transferred beginning with octet 1.

4.12.6.2.2.5 The bits of each octet shall be transferred beginning with bit 1.

4.12.6.2.2.6 The first bit transferred of the logical channel group number, logical channel number, P(R) and P(S) shall be the arithmetically least significant bit.

4.12.6.2.3 *Logical channels*

4.12.6.2.3.1 Each data link shall carry up to 4 096 logical channels.

4.12.6.2.3.2 Each logical channel shall be designated by a logical channel identifier, a number between 0 and 4 095, inclusive, which equals the logical channel group number multiplied by 2^8 and added to the logical channel number.

4.12.6.2.3.3 On each data link used to construct a PVC, a logical channel identifier between 1 and 4 095, inclusive, shall be assigned solely to that PVC.

4.12.6.2.3.4 The logical channel identifier assigned to a PVC on each data link shall not be required to be identical to the logical channel identifiers assigned to the same PVC on other data links.

4.12.6.2.3.5 On each data link, and when specified by the procedures described below, a centre shall transfer RESTART REQUEST and RESTART CONFIRMATION before transferring any other packets.

4.12.6.2.3.6 On each logical channel, and when specified by the procedures described below, a centre shall transfer RESET REQUEST and RESET CONFIRMATION before transferring any other packets on that logical channel.

4.12.6.2.3.7 A logical channel shall be in one of the following states:

a) unassigned, indicating the logical channel has not been assigned to carry a PVC;

b) restart, indicating that the procedure for restart has been initiated but not completed;

c) reset, indicating that the procedure for reset has been initiated but not completed;

d) flow control ready, indicating that the procedure for data transfer is being executed.

4.12.6.2.3.8 In the event of a restart, reset, reset time-out procedure error, outage or restoration of service, the operator shall be informed, along with the meaning of resetting cause fields and diagnostic codes as required.

4.12.6.2.4 *Receiving unknown packets and packets of less than three octets in length*

4.12.6.2.4.1 A centre which receives a packet with a general format identifier not equal to one of the general format identifiers specified in 4.12.6.2.2.1 above shall discard the packet.

4.12.6.2.4.2 A centre which receives a packet of less than two octets in length shall discard the packet.

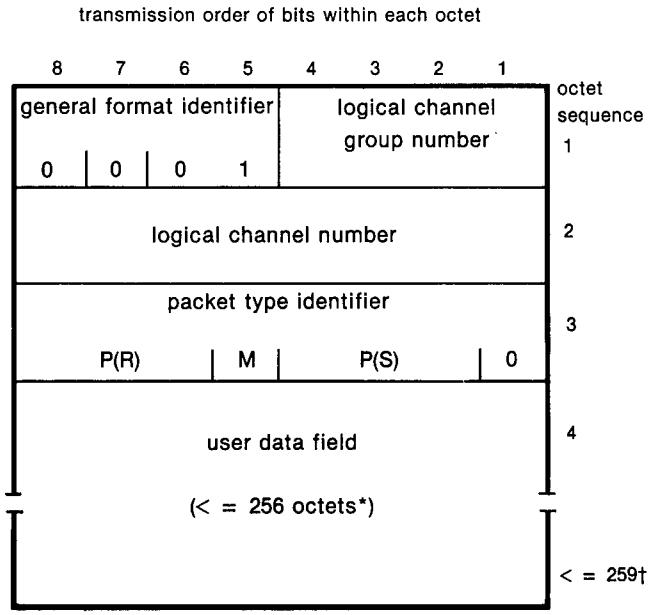
4.12.6.2.4.3 A centre which receives a packet of at least two but less than three octets in length shall:

a) if the logical channel is in the unassigned, restart or reset state, discard the packet;

b) if the logical channel is in the flow control ready state:

execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic field indicating "packet type invalid when in flow control ready state";

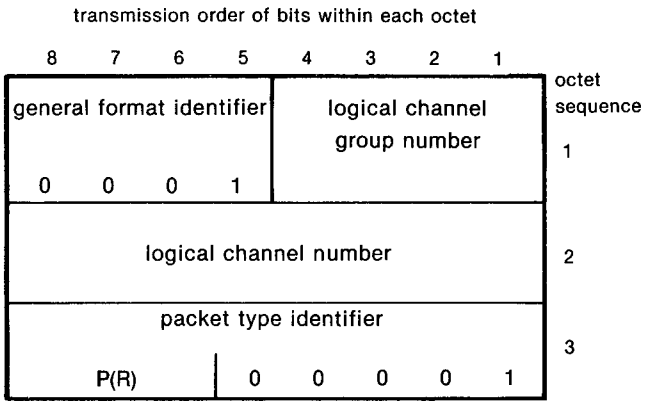
c) if the logical channel is in the flow control ready state, and the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state:



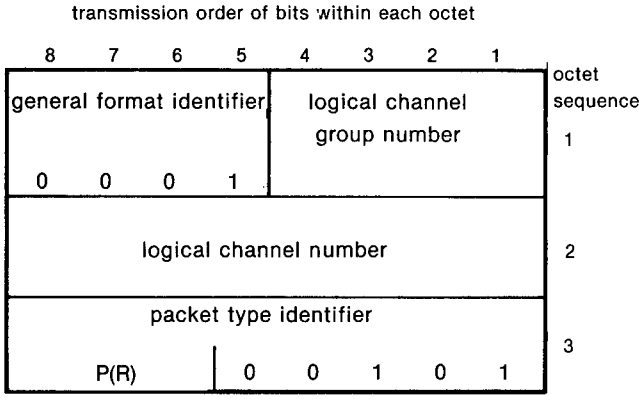
* Public data networks operating in the packet mode and connected with CIDIN using procedures described in ITU CCITT Recommendation X.25-1981 may limit the user data field to not more than 128 octets.

† Public data networks operating in the packet mode and connected with CIDIN using procedures described in ITU CCITT Recommendation X.25-1981 may limit data packets to not more than 131 octets.

Data packet format



RR packet format



RNR packet format

transmission order of bits within each octet

8	7	6	5	4	3	2	1	octet sequence
general format identifier				logical channel group number				1
0	0	0	1					
logical channel number								2
packet type identifier								3
0	0	0	1	1	0	1	1	
resetting cause field								4
diagnostic code								5

Reset request packet format

transmission order of bits within each octet

8	7	6	5	4	3	2	1	octet sequence
general format identifier				logical channel group number				1
0	0	0	1	0	0	0	0	
logical channel number								2
0	0	0	0	0	0	0	0	
packet type identifier								3
1	1	1	1	1	0	1	1	
restarting cause field								4
0	0	0	0	0	0	0	0	
diagnostic code								5

Restart request packet format

transmission order of bits within each octet

8	7	6	5	4	3	2	1	octet sequence
general format identifier				logical channel group number				1
0	0	0	1					
logical channel number								2
packet type identifier								3
0	0	0	1	1	1	1	1	

Reset confirmation packet format

transmission order of bits within each octet

8	7	6	5	4	3	2	1	octet sequence
general format identifier				logical channel group number				1
0	0	0	1	0	0	0	0	
logical channel number								2
0	0	0	0	0	0	0	0	
packet type identifier								3
1	1	1	1	1	1	1	1	

Restart confirmation packet format

execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic field indicating "packet type invalid when in flow control ready state".

4.12.6.2.4.4 A centre which receives a packet with a packet type identifier not defined in 4.12.6.2.2.1 above shall:

a) if the logical channel is in the unassigned, restart or reset state, discard the packet;

b) if the logical channel is in the flow control ready state:

execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic field indicating "packet type invalid on PVCs";

c) if the logical channel is in the flow control ready state, and the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state:

execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic field indicating "packet type invalid on PVCs".

4.12.6.2.5 *Procedure for initialization*

4.12.6.2.5.1 To simultaneously initialize all logical channels conveyed over a single data link, a centre shall:

execute the procedure for restart with the diagnostic code indicating "no additional information".

4.12.6.2.6 *Procedure for data transfer*

4.12.6.2.6.1 The following descriptions shall apply to the data transfer procedure:

a) The transfer lower window edge is the oldest P(S) number associated with the transfer (outgoing) direction of packets whose corresponding data packet has not yet been acknowledged by a P(R) transferred from the receiving centre.

b) The receive lower window edge is the oldest P(S) number associated with the receive (incoming) direction of packets whose corresponding data packet has not yet been acknowledged by a P(R) transferred from the receiving centre.

c) The window size W is the maximum number of packets which shall be transferred in a given direction on a logical channel before waiting for an acknowledgement from the receiving centre of the data packet with P(S) equal to the transfer lower window edge.

4.12.6.2.6.2 The data transfer procedure shall operate on each logical channel in the flow control ready state, independently from any other logical channel on that data link.

4.12.6.2.6.3 The data transfer procedure shall operate in each direction of data flow, independently from the opposite direction of data flow.

4.12.6.2.6.4 When a logical channel enters the flow control ready state, the receive and transfer lower window edges shall be set to 0.

4.12.6.2.6.5 W shall be 7.

Note.— Public data networks operating in the packet mode and connected with CIDIN using procedures described in ITU CCITT Recommendation X.25-1981 may require W to be some other value between 2 and 6, inclusive.

4.12.6.2.6.6 Arithmetic on lower window edges, P(S) and P(R) shall be performed modulo 8.

4.12.6.2.6.7 *Receiving data packets*

4.12.6.2.6.7.1 A centre which receives a data packet on a logical channel which is not in the flow control ready state shall discard the data packet.

4.12.6.2.6.7.2 A PVC transit centre which receives a data packet on a logical channel which is in the flow control ready state, and the corresponding logical channel is not in the flow control ready state, shall:

a) discard the data packet;

b) execute the procedure for reset on the logical channel from which the data packet was received, with the resetting cause field indicating "network congestion" and the diagnostic code indicating "no additional information".

4.12.6.2.6.7.3 A centre shall expect the first data packet received after a logical channel enters the flow control ready state to contain P(S) equal to 0.

4.12.6.2.6.7.4 A PVC transit centre which receives a data packet which is less than or equal to the maximum established length for data packets, and which contains P(S) equal to the next expected value of P(S), and which contains P(S) less than the receive lower window edge plus W, shall:

a) increment its next expected value of P(S) and, if this value differs from the receive lower window edge by more than one-half W, execute the procedure to update the receive lower window edge;

b) queue the data packet for transfer on the corresponding logical channel, without waiting for subsequent data packets;

c) if the P(R) is greater than or equal to the transfer lower window edge, and less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) set the transfer lower window edge to equal P(R);

2) if there exist any unacknowledged data packets which were transferred with P(S) less than the new

value of the transfer lower window edge, execute the procedure to update the receive lower window edge on the corresponding logical channel;

3) consider all unacknowledged data packets which have been transferred with P(S) less than the new value of the transfer lower window edge as acknowledged and delivered to the next centre;

d) if the P(R) is not greater than or equal to the transfer lower window edge, and not less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code field indicating "invalid P(R)";

2) execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "invalid P(R)".

4.12.6.2.6.7.5 A PVC termination centre which receives a data packet which is less than or equal to the maximum established length for data packets, and which contains P(S) equal to the next expected value of P(S), and which contains P(S) less than the receive lower window edge plus W, shall:

a) increment its next expected value of P(S) and, if this value differs from the receive lower window edge by more than one-half W, execute the procedure to update the receive lower window edge;

b) queue the data packet for processing by the transport level procedures;

c) if the P(R) is greater than or equal to the transfer lower window edge, and less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) set the transfer lower window edge to equal P(R);

2) consider all unacknowledged data packets which have been transferred with P(S) less than the new value of the transfer lower window edge as acknowledged and delivered to the next centre;

d) if the P(R) is not greater than or equal to the transfer lower window edge, and not less than or equal to the P(S) to be assigned to the next data packet for transfer:

execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code field indicating "invalid P(R)".

4.12.6.2.6.7.6 A centre which receives a data packet which is less than or equal to the maximum established length for data packets, and which contains P(S) equal to the next expected value of P(S), and which contains P(S) equal to or beyond the receive lower window edge plus W, shall:

a) discard the data packet;

b) execute the procedure for reset, with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "invalid P(S)";

c) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel, with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "invalid P(S)".

4.12.6.2.6.7.7 A centre which receives a data packet which is less than or equal to the maximum established length for data packets, and which contains P(S) not equal to the next expected value of P(S), shall:

a) discard the data packet;

b) execute the procedure for reset, with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "invalid P(S)";

c) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel, with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "invalid P(S)".

4.12.6.2.6.7.8 A centre which receives a data packet greater than the maximum established length for data packets shall:

a) discard the data packet;

b) execute the procedure for reset, with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet too long";

c) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel, with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet too long".

4.12.6.2.6.8 *Transferring RECEIVE NOT READY*

4.12.6.2.6.8.1 A centre which is becoming temporarily unable to accept further data packets shall transfer a RECEIVE NOT READY with P(R) equal to the receive lower window edge.

4.12.6.2.6.9 *Receiving RECEIVE NOT READY*

4.12.6.2.6.9.1 A centre which receives a RECEIVE NOT READY on a logical channel which is not in the flow control ready state shall discard the RECEIVE NOT READY.

4.12.6.2.6.9.2 A centre which receives a RECEIVE NOT READY of three octets in length shall:

a) if the P(R) is greater than or equal to the transfer lower window edge, and less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) set the transfer lower window edge to equal P(R);

2) consider all unacknowledged data packets which have been transferred with P(S) less than the new value of the transfer lower window edge as acknowledged and delivered to the next centre;

3) stop transferring data packets until a RECEIVE READY is received or the logical channel re-enters the flow control ready state;

b) if the P(R) is not greater than or equal to the transfer lower window edge, and not less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code field indicating "invalid P(R)";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code field indicating "invalid P(R)".

4.12.6.2.6.9.3 A centre which receives a RECEIVE NOT READY greater than three octets in length shall:

a) execute the procedure for reset, with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet too long";

b) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel, with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet too long".

4.12.6.2.6.10 *Transferring RECEIVE READY*

4.12.6.2.6.10.1 A centre which was becoming temporarily unable to accept further data packets and thus transferred one or more RECEIVE NOT READYs, and which subsequently has become able to accept further data packets, shall transfer a RECEIVE READY with P(R) equal to the receive lower window edge.

4.12.6.2.6.11 *Receiving RECEIVE READY*

4.12.6.2.6.11.1 A centre which receives a RECEIVE READY on a logical channel which is not in the flow control ready state shall discard the RECEIVE READY.

4.12.6.2.6.11.2 A centre which receives a RECEIVE READY of three octets in length shall:

a) if the P(R) is greater than or equal to the transfer lower window edge, and less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) set the transfer lower window edge to equal P(R);

2) consider all unacknowledged data packets which have been transferred with P(S) less than the new value of the transfer lower window edge as acknowledged and delivered to the next centre;

3) resume transferring data packets;

b) if the P(R) is not greater than or equal to the transfer lower window edge, and not less than or equal to the P(S) to be assigned to the next data packet for transfer:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code field indicating "invalid P(R)";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code field indicating "invalid P(R)".

4.12.6.2.6.11.3 A centre which receives a RECEIVE READY greater than three octets shall:

a) execute the procedure for reset, with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet too long";

b) if the centre is a PVC transit centre for the PVC assigned to the logical channel, execute the procedure for reset on the corresponding logical channel, with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet too long".

4.12.6.2.6.12 *Transferring data packets*

4.12.6.2.6.12.1 The first data packet transferred in each direction after a logical channel (re-enters the flow control ready state shall have P(S) equal to 0, and each subsequent data packet shall have a P(S) equal to the P(S) of the preceding data packet plus one.

4.12.6.2.6.12.2 When transferring a data packet, the procedure for updating the receive lower window edge shall be executed and the P(R) shall then be set equal to the value of the receive lower window edge.

4.12.6.2.6.12.3 A data packet shall not be transferred when the P(S) is equal to or beyond the transfer lower window edge plus W.

4.12.6.2.6.13 *Procedures for updating the receive lower window edge*

4.12.6.2.6.13.1 A PVC transit centre shall set the receive lower window edge equal to the next expected P(S).

4.12.6.2.6.13.2 A PVC termination centre shall set the receive lower window edge to equal the next expected P(S).

4.12.6.2.6.13.3 A centre which has changed the value of the receive lower window edge, and which cannot send a data packet, and which remains temporarily unable to accept further data packets, shall transfer a RECEIVE NOT READY.

4.12.6.2.6.13.4 A centre which has changed the value of the receive lower window edge, and which cannot send a data packet, and which is able to accept further data packets, shall transfer a RECEIVE READY.

4.12.6.2.7 *Procedure for reset*

4.12.6.2.7.1 The procedure for reset shall be used to reinitialize a logical channel.

4.12.6.2.7.2 A centre shall not initiate the procedure for reset when the logical channel is in the restart or unassigned state.

4.12.6.2.7.3 A centre shall initiate the procedure for reset as follows:

a) discard all packets waiting to be transferred or acknowledged on the logical channel;

b) cause the logical channel to enter the reset state;

c) transfer a RESET REQUEST;

d) start a 180-second timer T22.

Note.— Public data networks operating in the packet mode and connected with CIDIN using procedures described in ITU CCITT Recommendation X.25-1981 may require the resetting cause field to indicate "centre-originated reset".

4.12.6.2.7.4 *Receiving RESET REQUEST*

4.12.6.2.7.4.1 A centre which receives a RESET REQUEST of three octets in length when the logical channel is in the flow control ready state shall:

a) discard all packets waiting to be transferred or acknowledged on the logical channel;

b) immediately transfer a RESET CONFIRMATION;

c) cause the logical channel to re-enter the flow control ready state;

d) if the centre is a PVC transit centre for the PVC assigned to the logical channel and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with an identical diagnostic code and with a resetting cause field as follows:

Resetting cause field received	*Resetting cause field transferred*
centre-originated reset	centre-originated reset
out of order	out of order
remote procedure error	remote procedure error
local procedure error	remote procedure error
network congestion	network congestion
remote centre operational	remote centre operational
network operational	network operational

e) if the centre is a PVC termination centre for the PVC assigned to the logical channel, notify the transport level procedure that a reset has occurred.

4.12.6.2.7.4.2 A centre which receives a RESET REQUEST of three octets in length when the logical channel is in the reset state shall:

a) cancel T22;

b) cause the logical channel to enter the flow control ready state;

c) if the centre is a PVC termination centre for the PVC assigned to the logical channel, notify the transport level procedure that a reset has occurred.

4.12.6.2.7.4.3 A centre which receives a RESET REQUEST of three octets in length when the logical channel is in the restart or unassigned state shall discard the RESET REQUEST.

4.12.6.2.7.4.4 A centre which receives a RESET REQUEST of greater than three octets in length shall:

a) if the logical channel is in the flow control ready or reset state:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet too long";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet too long";

b) if the logical channel is in the restart or unassigned state, discard the RESET REQUEST.

4.12.6.2.7.5 *Receiving RESET CONFIRMATION*

4.12.6.2.7.5.1 A centre which receives a RESET CONFIRMATION of three octets in length when the logical channel is in the flow control ready state shall:

a) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet type invalid when in flow control ready state";

b) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet type invalid when in flow control ready state".

4.12.6.2.7.5.2 A centre which receives a RESET CONFIRMATION of three octets in length when the logical channel is in the reset state shall:

a) cancel T22;

b) cause the logical channel to enter the flow control ready state;

c) if the centre is a PVC termination centre for the PVC assigned to the logical channel, notify the transport level procedure that a reset has occurred.

4.12.6.2.7.5.3 A centre which receives a RESET CONFIRMATION of three octets in length when the logical channel is in the restart or unassigned state shall discard the RESET CONFIRMATION.

4.12.6.2.7.5.4 A centre which receives a RESET CONFIRMATION of greater than three octets in length shall:

a) if the logical channel is in the reset state:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet too long";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet too long";

b) if the logical channel is in the flow control ready state:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "packet type invalid when in flow control ready state";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "packet type invalid when in flow control ready state";

c) if the logical channel is in the restart or unassigned state, discard the RESET CONFIRMATION.

4.12.6.2.7.6 When T22 expires, the centre shall:

a) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "timer expired for reset";

b) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "timer expired for reset".

4.12.6.2.8 *Procedure for restart*

4.12.6.2.8.1 A centre shall initiate the procedure for restart as follows:

a) transfer a RESTART REQUEST;

b) discard all packets waiting to be transferred or acknowledged on each logical channel;

c) cause each logical channel to enter the restart state;

d) start a 180-second timer T20.

4.12.6.2.8.2 *Receiving RESTART REQUEST*

4.12.6.2.8.2.1 A centre which receives a RESTART REQUEST with a logical channel identifier equal to 0 and of three octets in length, and whose logical channels are not in the restart state, shall:

a) discard all packets waiting to be transferred or acknowledged;

b) immediately transfer a RESTART CONFIRMATION;

c) cause each logical channel assigned to carry a PVC to re-enter the flow control ready state;

d) cause each logical channel not assigned to carry a PVC to re-enter the unassigned state;

e) for each PVC assigned to a logical channel carried on the data link:

1) if the centre is a PVC transit centre, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "network operational" and the diagnostic code equalling the diagnostic code of the RESTART REQUEST;

2) if the centre is a PVC termination centre, notify the transport level procedure that a restart is occurring.

4.12.6.2.8.2.2 A centre which receives a RESTART REQUEST with a logical channel identifier equal to 0 and of three octets in length, and whose logical channels are in the restart state, shall:

a) cancel T20;

b) cause each logical channel assigned to carry a PVC to enter the flow control ready state;

c) cause each logical channel not assigned to carry a PVC to enter the unassigned state;

d) for each PVC assigned to a logical channel carried on the data link:

1) if the centre is a PVC transit centre, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "network operational" and the diagnostic code equalling the diagnostic code of the RESTART REQUEST;

2) if the centre is a PVC termination centre, notify the transport level procedure that a restart is occurring.

4.12.6.2.8.2.3 A centre which receives a RESTART REQUEST with a logical channel identifier equal to 0 and of greater than three octets in length shall:

execute the procedure for restart with the diagnostic code indicating "packet too long".

4.12.6.2.8.2.4 A centre which receives a RESTART REQUEST with a logical channel identifier not equal to 0 shall:

a) if the indicated logical channel is in the flow control ready state:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "restart packet received with non-zero logical channel identifier";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "restart packet received with non-zero logical channel identifier";

b) if the indicated logical channel is in the restart, reset or unassigned state, discard the RESTART REQUEST.

4.12.6.2.8.3 *Receiving RESTART CONFIRMATION*

4.12.6.2.8.3.1 A centre which receives a RESTART CONFIRMATION with a logical channel identifier equal to 0 and of three octets in length, and whose logical channels are not in the restart state, shall:

execute the procedure for restart with the diagnostic code indicating "packet type invalid when not in restart state".

4.12.6.2.8.3.2 A centre which receives a RESTART CONFIRMATION with a logical channel identifier equal to 0 and of three octets in length, and whose logical channels are in the restart state, shall:

a) cancel T20;

b) cause each logical channel assigned to carry a PVC to enter the flow control ready state;

c) cause each logical channel not assigned to carry a PVC to enter the unassigned state;

d) for each PVC assigned to a logical channel carried on the data link:

1) if the centre is a PVC transit centre and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "network operational" and the diagnostic code equalling the diagnostic code of the RESTART REQUEST;

2) if the centre is a PVC termination centre, notify the transport level procedure that a restart is occurring.

4.12.6.2.8.3.3 A centre which receives a RESTART CONFIRMATION with a logical channel identifier equal to 0 and of greater than three octets in length shall:

execute the procedure for restart with the diagnostic code indicating "packet too long".

4.12.6.2.8.3.4 A centre which receives a RESTART CONFIRMATION with a logical channel identifier not equal to 0 shall:

a) if the indicated logical channel is in the flow control ready state:

1) execute the procedure for reset with the resetting cause field indicating "local procedure error" and the diagnostic code indicating "restart packet received with non-zero logical channel identifier";

2) if the centre is a PVC transit centre for the PVC assigned to the logical channel, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "remote procedure error" and the diagnostic code indicating "restart packet received with non-zero logical channel identifier";

b) if the indicated logical channel is in the restart, reset or unassigned state, discard the packet.

4.12.6.2.8.4 When T20 expires, the centre shall:

execute the procedure for restart with the diagnostic code indicating "timer expired for restart".

4.12.6.2.9 *Procedure when link level is out of order*

4.12.6.2.9.1 A centre which determines link level is out of order on a particular data link shall:

a) discard all packets waiting to be transferred on any logical channel carried on the data link;

b) for each PVC assigned to a logical channel carried on the data link:

1) if the centre is a PVC transit centre, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "out of order" and the diagnostic code indicating "no additional information";

2) if the centre is a PVC termination centre, notify the transport level procedure that the packet level is out of order.

4.12.6.2.9.2 A centre which determines that the link level is no longer out of order shall:

a) execute the procedure for restart;

b) for each PVC assigned to a logical channel carried on the data link:

1) if the centre is a PVC transit centre, and the corresponding logical channel is in the flow control ready state, execute the procedure for reset on the corresponding logical channel with the resetting cause field indicating "network operational" and the diagnostic code indicating "no additional information";

2) if the centre is a PVC termination centre, notify the transport level procedure that the packet level is no longer out of order.

4.12.6.2.10 *Diagnostic code values*

	Bits of diagnostic code							
Diagnostic indication	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
No additional information	0	0	0	0	0	0	0	0
Invalid P(S)	0	0	0	0	0	0	0	1
Invalid P(R)	0	0	0	0	0	0	1	0
Packet type invalid when not in restart state	0	0	0	1	0	0	0	1
Packet type invalid when in flow control ready state	0	0	0	1	1	0	1	1
Packet type invalid on PVCs	0	0	1	0	0	0	1	1
Packet too short	0	0	1	0	0	1	1	0
Packet too long	0	0	1	0	0	1	1	1
Restart packet with non-zero logical channel identifier	0	0	1	0	1	0	0	1
Timer expired for reset	0	0	1	1	0	0	1	1
Timer expired for restart	0	0	1	1	0	1	0	0

Note.— Other bit combinations reserved.

4.12.6.2.11 *Resetting cause field values*

	Bits of resetting cause field							
Resetting cause indication	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
Centre-originated reset	0	0	0	0	0	0	0	0
Out of order	0	0	0	0	0	0	0	1
Remote procedure error	0	0	0	0	0	0	1	1
Local procedure error	0	0	0	0	0	1	0	1
Network congestion	0	0	0	0	0	1	1	1
Remote centre operational	0	0	0	0	1	0	0	1
Network operational	0	0	0	0	1	1	1	1

Note.— Other bit combinations reserved.

4.12.6.2.12 *Restarting cause field values*

4.12.6.2.12.1 A centre shall always set the restarting cause field to equal 0.

Note.— Public data networks operating in the packet mode and connected with CIDIN using procedures described in ITU CCITT Recommendation X.25-1981 may also transfer restarting cause fields of the following values:

	Bits of restarting cause field							
Restarting cause indication	8	7	6	5	4	3	2	1
Local procedure error	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*
Network congestion	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*
Network operational	*0*	*0*	*0*	*0*	*0*	*1*	*1*	*1*

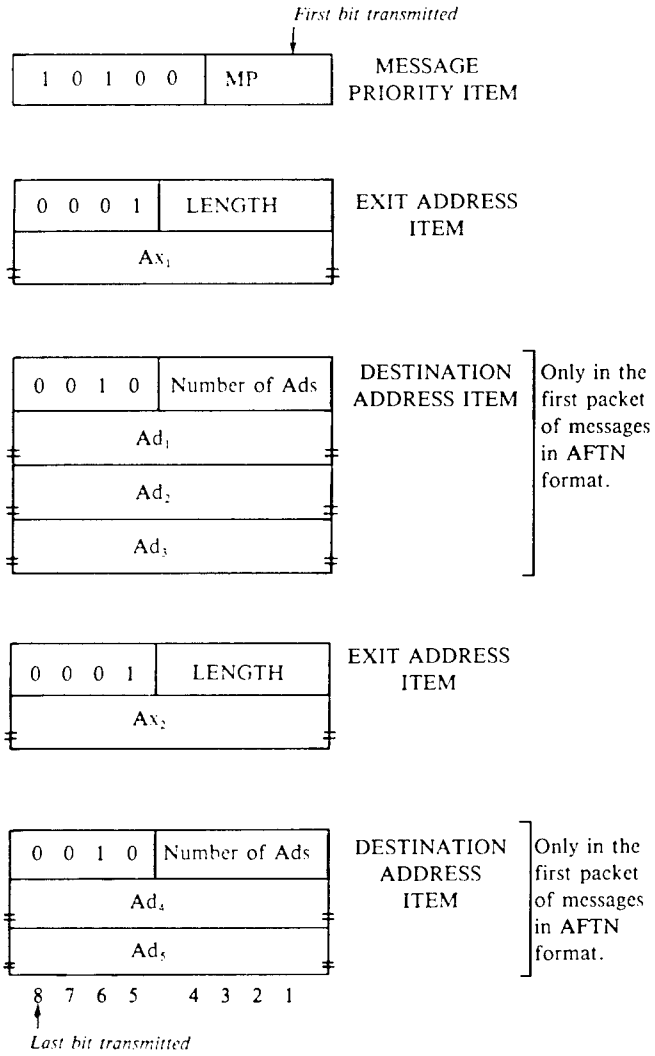
4.12.6.3 *The CIDIN packet protocol*

4.12.6.3.1 *The CIDIN packet header format*

4.12.6.3.1.1 The CIDIN packet header shall contain the following components:

— Message priority indicator (MP)
— Exit address(es) (Ax)
— Destination address(es) (Ad)

4.12.6.3.1.2 The CIDIN packet header shall be generated by the entry centre and shall be interpreted by relay centres and exit centres receiving the CIDIN packets.



4.12.6.3.1.3 The components contained in the octets of the CIDIN packet header shall be the following.

4.12.6.3.1.3.1 The first item shall contain a three bit message priority indicator (MP, bits 1, 2 and 3) which shall be interpreted as follows:

—000 Priority 1
—001 Priority 2
—010 Priority 3
—011 Priority 4
—100 Priority 5
—101 Priority 6
—110 Priority 7
—111 Priority 8

Bit 4 is reserved for future use and shall be set to zero.

4.12.6.3.1.3.1.1 The highest CIDIN priority shall be reserved for CIDIN network management messages. The remaining priorities shall be available for user messages.

4.12.6.3.1.3.2 The following item of the CIDIN packet header shall contain the address(es) of the exit centre(s). The exit address normally consists of the first two characters of the location indicator of the concerned exit centre. In those cases where a station is directly connected to CIDIN, i.e. performs exit/entry functions, the exit address shall consist of the first two characters of the location indicator of the concerned CIDIN station followed by as many additional characters as necessary to uniquely identify the station. The total number of characters in an exit address shall not exceed 8. The Ax values of all binary ones and all binary zeros shall be reserved. The number of octets used by each Ax shall be indicated in bits 1-4 of the first octet of each exit address item. There shall be an exit address item for each Ax to which the CIDIN packet is to be transmitted. The maximum number of exit addresses in a CIDIN message shall be 16.

4.12.6.3.1.3.3 In the case of a message in AFTN format the destination address(es) shall be included in the first packet and shall be inserted immediately following each associated exit centre address. (See 4.12.6.3.1.2 above).

4.12.6.3.1.3.4 The number of destination addresses associated with an exit centre address shall be indicated in bits 1-4 of each destination address item. The length of each destination address shall be 8 octets.

4.12.6.3.1.3.5 When the number of destination addresses associated with an exit centre address exceeds 16 an additional destination address item shall be added following the item containing the first 16 destination addresses.

4.12.6.3.2 *CIDIN packet procedures*

4.12.6.3.2.1 *General.* The CIDIN packet procedures shall be defined for:

a) entry centres;

b) relay centres;

c) exit centres.

4.12.6.3.2.2 *CIDIN packet header generation*

4.12.6.3.2.2.1 For each information message submitted, the CIDIN packet level shall accept the following elements from the transport level:

a) message content, segmented such that the maximum packet length would not be exceeded if the routing analysis were to require output on a single CIDIN circuit;

b) exit centre address(es);

c) CIDIN message priority;

d) destination address(es), for inclusion in the first packet only.

4.12.6.3.2.2.2 The entry centre shall generate the packet header based on the information given in b), c) and d), and based on the information derived in the routing analysis process.

4.12.6.3.2.3 *Routing and relay of CIDIN packets*

4.12.6.3.2.3.1 All packets shall be sent by the predetermined route available to effect delivery to the exit centre(s). Where the routing requires that a CIDIN packet be sent to the relay/entry centre from which it was received, the next most expeditious route shall be used.

4.12.6.3.2.3.2 Centres shall be interconnected by one or more PVCs. The route shall be defined as that which requires the least number of PVC traversals to reach the exit centre.

4.12.6.3.2.3.2.1 It shall be permissible to choose between two or more equally expeditious predetermined routes by any suitable method.

4.12.6.3.2.4 *Selection of PVC for transmission of a CIDIN packet*

4.12.6.3.2.4.1 Each CIDIN switching centre shall maintain a routing table relating destination addresses to primary exit addresses and agreed secondary exit addresses and including the primary and alternative outgoing PVCs to each exit address.

4.12.6.3.2.5 *Transmission of CIDIN packets*

4.12.6.3.2.5.1 Higher priority packets shall be transmitted before lower priority packets.

4.12.6.3.2.5.2 The relay of CIDIN packets shall not be delayed unnecessarily.

4.12.6.3.2.5.2.1 The relay of CIDIN packets shall not wait for complete CIDIN message receipt.

4.12.6.3.2.5.3 Packets having the same priority shall be transmitted in the order in which they are received.

4.12.6.3.2.6 *Action on packets with errors*

4.12.6.3.2.6.1 When a centre receives a packet that does not contain a complete packet header, it shall discard that packet.

4.12.6.3.2.7 *Loss of communication*

4.12.6.3.2.7.1 When a relay centre loses all communication with an exit centre it shall:

a) discard all packets addressed to that exit centre;

b) for multi-addressed packets, transmit the packets to those addresses for which it has a communications possibility;

c) inform the operator of the action taken.

4.12.6.3.2.7.2 When a CIDIN switching centre ceases operation, it shall discard all packets which are neither originated by nor addressed to it.

4.12.6.3.2.8 *Handling of multiple dissemination*

4.12.6.3.2.8.1 A centre which receives a CIDIN packet for multiple dissemination shall determine the outgoing PVC on which the CIDIN packets of the CIDIN message shall be transmitted for each Ax.

4.12.6.3.2.8.2 The CIDIN packet header of packets transmitted on each outgoing PVC shall contain only the exit centre addresses and destination addresses (first packet of messages in AFTN format only) to be reached via the particular PVC. The relay of CIDIN packets shall not result in unnecessary multiplication of packets. Exit centre addresses and destination addresses (messages in AFTN format only) not to be reached via the particular PVC shall be stripped. This process shall be called address stripping.

Note.— Guidance material on address stripping is contained in Volume II, Attachment C.

4.12.6.3.2.8.3 Relay centres shall not alter the received CIDIN packet headers of CIDIN packets that are transmitted on a single outgoing PVC for all Axs specified.

4.12.6.3.2.8.4 Relay centres shall compose new CIDIN packet headers for CIDIN packets that are transmitted on more than one outgoing PVC and apply address stripping.

4.12.6.3.2.8.5 Centres detecting their own address among the Axs shall act as exit centre for their own address, and as relay centre for the other Axs.

4.12.6.4 *The transport protocol*

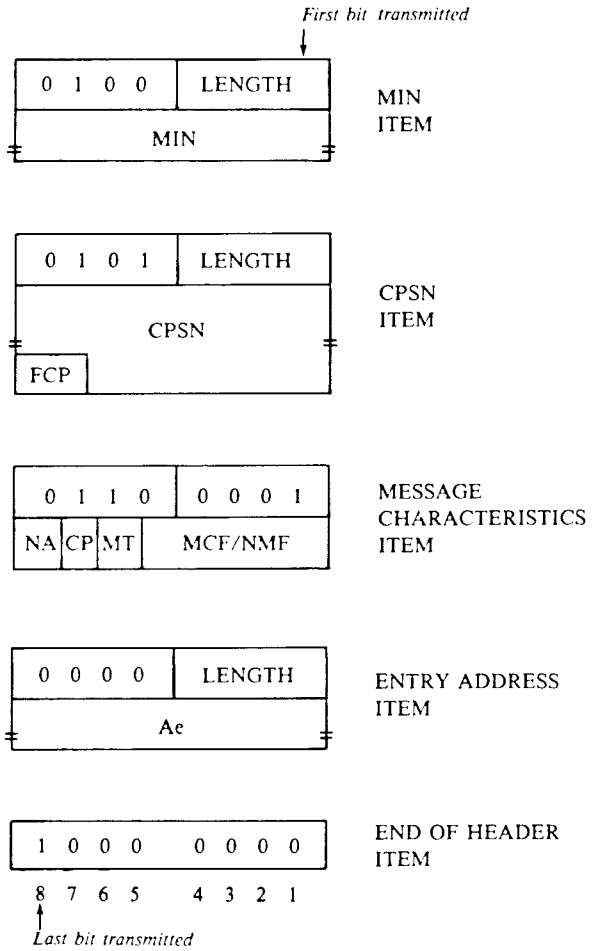
4.12.6.4.1 *The transport header format*

4.12.6.4.1.1 The transport header shall contain the following components:

— Message identification number	(MIN)
— CIDIN packet sequence number	(CPSN)
— Final CIDIN packet indicator	(FCP)
— Message code and format or network management field	(MCF/NMF)
— Message type indicator	(MT)
— Conversation protect indicator	(CP)
— Network acknowledgement indicator	(NA)
— Entry address	(Ae)
— End of header	(EOH)

4.12.6.4.1.2 The transport header shall be generated by the entry centre and shall be interpreted by the exit centre(s) receiving the CIDIN packet.

4.12.6.4.1.3 The transport header shall consist of:



4.12.6.4.1.4 The components contained within the transport header shall be as follows:

4.12.6.4.1.4.1 The first item of the transport header shall contain the message identification number (MIN) expressed in binary form. The low order bit of the MIN shall be bit 1 in the second octet of the item. Any number of octets between one and fifteen shall be employed to provide the MIN. The number of octets used by the MIN shall be indicated in bits 1-4 of the first octet of this item. The MIN shall identify the number of a CIDIN message transmitted by a specific entry centre.

4.12.6.4.1.4.2 **Recommendation.**— *Where the volume of traffic requiring acknowledgement so permits, the number of MINs used should be limited.*

4.12.6.4.1.4.2.1 At each entry centre a common pool of MINs shall be used for information and network management messages requiring network acknowledgement.

4.12.6.4.1.4.3 The second item of the transport header shall contain the following two components:

1) A CIDIN packet sequence number (CPSN), beginning in the second octet of this item, shall identify the sequence number of each CIDIN packet of a message. The CPSN shall be assigned in sequence beginning with X0000000. The low order bit of the CPSN shall be bit 1 of the second octet of this item.

   Note.—

   a) If the CPSN item consists of two octets including the header item then the X (bit 8) in the second octet is the FCP component.

   b) In the header item a length indication of 0000 is not used and one octet of information is represented by a length indication of 0001.

2) A final CIDIN packet (FCP) component (bit 8 of the last octet of this item) which shall be set to:

   —1 to indicate the last CIDIN packet of a multipacket message, or the only packet of a single-packet message;

   —0 to indicate all other packets.

3) The number of octets used by the CPSN and FCP shall be indicated in bits 1-4 of the first octet of this item.

4.12.6.4.1.4.4 The third item of the transport header shall contain the following four components:

1) A five bit component contained in bits 1 to 5, interpreted according to the setting of bit 6 as either:

   — a message code and format (MCF) component, designating which one of the code and format types specified (see Table 4-7) is employed in the UDF for CIDIN information messages; or

   — a network management function (NMF) component, designating one of 32 network management message types and the means for interpreting the UDF (see Table 4-7).

2) A message type (MT) component (bit 6) which shall be set to:

   —0 to indicate an information message;

   —1 to indicate a network management message.

3) A one bit conversation protect (CP) component (bit 7) is reserved for future use.

4) A network acknowledgement (NA) component (bit 8) which shall be set to:

   —0 to indicate acknowledgement not required;

   —1 to indicate acknowledgement required.

Table 4-7. Significance of MCF and NMF indicators

MCF/NMF value					*Meaning*	
b_5	b_4	b_3	b_2	b_1	*MCF (MT = 0)*	*NMF (MT = 1)*
0	0	0	0	0	Reserved	Reserved
0	0	0	0	1	Not yet allocated	Not yet allocated
0	0	0	1	0	AFTN	Enquiry
0	0	0	1	1	Not yet allocated	Acknowledgement
0	0	1	0	0	”	Enquiry response
0	0	1	0	1	”	Not yet allocated
0	0	1	1	0	”	”
0	0	1	1	1	”	”
0	1	0	0	0	”	MCF error
0	1	0	0	1	Not yet allocated	Not yet allocated
0	1	0	1	0	”	”
0	1	0	1	1	”	”
0	1	1	0	0	”	”
0	1	1	0	1	”	”
0	1	1	1	0	”	”
0	1	1	1	1	Not yet allocated	Not yet allocated
1	0	0	0	0	”	”
1	0	0	0	1	”	”
1	0	0	1	0	”	”
1	0	0	1	1	”	”
1	0	1	0	0	”	”
1	0	1	0	1	Not yet allocated	Not yet allocated
1	0	1	1	0	”	”
1	0	1	1	1	”	”
1	1	0	0	0	”	”
1	1	0	0	1	”	”
1	1	0	1	0	”	”
1	1	0	1	1	”	”
1	1	1	0	0	”	”
1	1	1	0	1	Reserved for regional use	”
1	1	1	1	0	Reserved for regional use	”
1	1	1	1	1	Reserved for regional use	Reserved

4.12.6.4.1.4.5 The fourth item of the transport header shall contain the entry address (Ae) which identifies the CIDIN switching centre that originates the CIDIN message on the CIDIN. The entry address normally consists of the first two characters of the location indicator of the concerned entry centre. In those cases where a station is directly connected to CIDIN, i.e. performs entry/exit functions, the entry address shall consist of the first two characters of the location indicator of the concerned CIDIN station followed by as many additional characters as necessary to uniquely identify the station. The total number of characters in an entry address shall not exceed 8. The Ae values of all binary ones and all binary zeros shall be reserved. The number of octets used by the Ae shall be indicated in bits 1-4 of the first octet of this item.

4.12.6.4.1.4.6 The last item of the transport header shall be the end of header (EOH) item, as shown in 4.12.6.4.1.3 above.

4.12.6.4.2 *Transport procedures*

4.12.6.4.2.1 *General.* The transport procedures shall be defined for:

a) entry centres;

b) exit centres.

Relay centres shall not perform processing functions at the transport level.

4.12.6.4.2.2 *Transport header generation*

4.12.6.4.2.2.1 For each information message submitted, the entry centre shall accept the following elements:

a) message content (any approved code and format);

b) exit centre address(es);

c) destination addresses applicable to each exit centre address;

d) message priority;

e) message code/format;

f) requirement for acknowledgement;

g) requirement for uninterrupted conversation (future use);

h) requirement for priority interruptable conversation (future use).

Item c) shall be provided for messages in AFTN format.

4.12.6.4.2.2.2 The entry centre shall generate the appropriate transport header based on the information given in e), f), g) and h).

4.12.6.4.2.2.3 *Message identification number assignment*

4.12.6.4.2.2.3.1 The entry centre shall assign a MIN value to each message, from a pool of available numbers. MIN values shall be assigned in continuous numerical sequence.

4.12.6.4.2.2.3.2 For CIDIN messages which require network acknowledgement, a given MIN value shall not be reassigned to a new message until the corresponding network acknowledgement has been received by the entry centre.

4.12.6.4.2.3 *Information message handling*

4.12.6.4.2.3.1 The information message content received from the applications software shall be placed in one or more UDF, with no addition or modification (see Figure 4-4). This shall be the responsibility of the entry centre.

4.12.6.4.2.4 *Network management message handling*

4.12.6.4.2.4.1 The entry centre shall generate and respond to network management messages using the standard format. Network management UDF contents are generated by the entry centre.

Note.— The format of the network management messages is contained in Table 4-8.

4.12.6.4.2.5 *Recovery procedure for messages on CIDIN*

4.12.6.4.2.5.1 *Handling of messages requiring acknowledgement on the transport level*

4.12.6.4.2.5.1.1 For messages requiring network acknowledgement the entry centre shall, before initiating transmission, set the NA bit to "1" and temporarily store the message for possible retransmission. After sending the last frame of the message a response time-out (TMR), based on the transit time to the most remote exit centre, shall be initiated.

4.12.6.4.2.5.1.2 At the exit centre, once a message with the NA bit set to "1" has been completely assembled and recorded, a network acknowledgement message shall be sent back to the entry centre.

Note.— The format of the acknowledgement message is contained in Table 4-8.

4.12.6.4.2.5.1.3 Upon receiving a valid network acknowledgement response from all addressed exit centres for the complete message, the entry centre shall remove the corresponding message from retransmission storage, and shall release the MIN value for future use.

4.12.6.4.2.5.2 *Action on detection of message loss*

4.12.6.4.2.5.2.1 If an entry centre does not receive a network acknowledgement message for a message sent with the NA bit set to "1", within a period of time (TMR) it shall retransmit the message with the same MIN value.

4.12.6.4.2.5.2.2 If a network acknowledgement message is still not obtained, the entry centre shall send an enquiry message to that exit centre, initiate a message response time-out (TEM) and shall stop transmissions of information messages to that exit centre.

4.12.6.4.2.5.2.3 When an entry centre fails to obtain an acknowledgement even after a retry to the primary exit centre associated with a given destination, and an agreed secondary exit centre exists for that destination, the entry centre shall transmit the message to the alternative exit centre. A different MIN shall be used. Further traffic for the destination shall be routed through the alternative exit centre until one of the ENQ messages periodically sent to the primary exit centre is acknowledged by that centre. At that time, traffic routing shall revert to the primary exit centre.

4.12.6.4.2.5.2.4 When a multiply disseminated message is not acknowledged by all the exit centres addressed, the entry centre, on expiry of time-out (TMR) shall re-transmit the message only to those exit centres which did not acknowledge the message. In this instance the exit centres shall retain packets of a message for a period of time (TNMA) and discard these packets if the message is not completed. This time TNMA shall be shorter than or equal to TMR.

Note.— The format of the enquiry message is contained in Table 4-8.

4.12.6.4.2.5.2.5 On receipt of an enquiry message, the exit centre shall acknowledge the enquiry message by transmitting an enquiry response message back to the entry centre.

Note.— The format of the enquiry response message is contained in Table 4-8.

4.12.6.4.2.5.2.6 Once the entry centre has received the enquiry response message, it shall resume sending information messages to that exit centre.

4.12.6.4.2.5.2.7 When a response to an enquiry message is not received within a period of time (TEM), the entry centre shall retransmit the enquiry message.

4.12.6.4.2.5.2.8 After complete and error-free receipt of the first packet to arrive of any message requiring network acknowledgement, the exit centre shall start a time-out (TNMA) for that message; the time-out shall be restarted each

Table 4-8. Format for network management messages

NETWORK MANAGEMENT MESSAGE			ACK	ENQ	Enquiry response	MCF error
COMMUNICATIONS CONTROL FIELD	CIDIN PACKET HEADER	MP	000			
		Ax	a)	b)	c)	a)
	TRANSPORT HEADER	MIN	next available			
		CPSN	all zero			
		FCP	1			
		MCF/NMF	see Table 4-7			
		MT	1			
		CP	0			
		NA	0			
		Ae	b)	a)	d)	b)
		EOH	0000 0001			
USER DATA FIELD			MIN of original information message, Ax of original information message and CPSN of last received CIDIN packet	NONE	NONE	MIN of original information message, Ax of original information message and CPSN of last received CIDIN packet

NOTES:

a) Use the Ae of the original information message.

b) Use the Ax of the original information message.

c) Use the Ae of the original management message.

d) Use the Ax of the original management message.

time a further CIDIN packet of the same message is received. The time-out shall be stopped when all packets of the message have been completely received.

4.12.6.4.2.5.2.9 When the exit centre time-out period expires before all packets of the message have been completely received, the exit centre shall discard the incomplete message.

4.12.6.4.2.6 *Handling of messages not requiring acknowledgement on the transport level*

4.12.6.4.2.6.1 After complete and error-free receipt of the first packet to arrive of any message not requiring network acknowledgement, the exit centre shall start a time-out (TNMA) for that message. The time-out shall be restarted each time a further CIDIN packet of the same message is received. The time-out shall be stopped when all packets of the message have been completely received.

4.12.6.4.2.6.2 When the exit centre time-out period expires before all packets of the message have been completely received, the exit centre shall discard the incomplete message.

4.12.6.4.2.7 *Handling of messages with unacceptable code/format combinations*

4.12.6.4.2.7.1 When an exit centre receives a message which is in a code and format for which it has no applications software, it shall discard the message, and send an MCF error message to the entry centre.

Note.— The format of the MCF error message is contained in Table 4-8.

4.12.6.4.2.7.2 On receipt of an MCF error message, the entry centre shall take what action it can (e.g. code conversion) to ensure that the information message concerned is retransmitted in an acceptable code/format combination.

4.12.6.4.2.8 *Handling of multiple dissemination messages*

4.12.6.4.2.8.1 For messages requiring multiple dissemination, the recovery procedures shall take place between the entry centre and all exit centres concerned.

4.13 Technical provisions relating to international air-ground data interchange

4.13.1 When operating in the synchronous mode, the data link shall be capable of code and byte independent transmission of digital data.

4.13.2 **Recommendation.—** *The data signalling rate should be chosen from among the following:*

600 bits/s
1 200 bits/s
*2 400 bits/s**
4 800 bits/s
9 600 bits/s

** preferred minimum data signalling rate.*

Note.— Application to high frequency aeronautical mobile channels may be looked upon as a special case where the convention 75 × 2^n bits/s is to be employed in the choice of a data signalling rate, where "n" is zero or a positive integer value.

4.13.3 **Recommendation.—** *When alphanumeric characters are used the International Alphabet No. 5 (IA-5), in whole or in parts thereof, shown in 4.12.1.2 above, should be used for the transmission of air-ground data.*

4.13.4 The serial transmission of units comprising an individual character of IA-5 shall be with the low order unit (b_1) transmitted first.

4.13.5 **Recommendation.—** *When IA-5 is used, each character should include an additional unit for parity in the eighth level position.*

4.13.6 When the provisions of 4.13.5 are applied, the sense of the character parity bit shall produce even parity in links which operate on the start-stop principle and odd parity in links using end-to-end synchronous operation.

4.13.7 **Recommendation.—** *The type of transmission for each data signalling rate should be chosen as follows:*

Data signalling rate	Type of transmission
600 bits/s	*Synchronous or asynchronous serial transmission*
1 200 bits/s	*Synchronous or asynchronous serial transmission*
2 400 bits/s	*Synchronous serial transmission*
4 800 bits/s	*Synchronous serial transmission*
9 600 bits/s	*Synchronous serial transmission*

4.14 Technical provisions relating to international aeronautical speech circuit switching and signalling

Note.— Guidance material on aeronautical speech circuit switching and signalling is contained in ICAO Circular 183.

4.14.1 The use of circuit switching and signalling to provide point-to-point speech circuits to interconnect area control centres not interconnected by dedicated circuits shall be by agreement between the Administrations concerned.

4.14.2 The application of aeronautical speech circuit switching and signalling shall be made on the basis of regional air navigation agreements.

4.14.3 **Recommendation.—** *Where implemented, aeronautical speech circuit switching and signalling should provide:*

a) priority access;

b) automatic call-back;

c) conference calling;

d) through switching facilities;

e) the capability of alternate routing, when necessary and feasible;

f) identification of originator for incoming calls, when necessary and feasible; and

g) call forwarding, when necessary and feasible.

Note 1.— Identification of originator is done by analysis of the originator's code which is transmitted on both signalling systems R2 and No. 5.

Note 2.— Call forwarding ensures that calls to operating positions which are temporarily not manned will be rerouted automatically to an appropriate operating position.

4.14.4 **Recommendation.—** *The characteristics of signalling tones used in aeronautical speech circuit switching and signalling should conform to ITU CCITT Signalling System No. 5 or to ITU CCITT Signalling System R2 as appropriate. Signalling tones on inter-regional trunks should conform to one of these ITU CCITT specifications as determined by agreement between the Administrations concerned.*

Note.— Details of ITU CCITT Signalling System No. 5 are contained in CCITT Yellow Book, Volume VI — Fascicle VI-2; details of ITU CCITT Signalling System R2 are contained in CCITT Yellow Book, Volume VI — Fascicle VI-4.

4.14.5 **Recommendation.—** *The characteristics of the ringing tone, the busy tone and the congestion tone used in aeronautical speech circuit switching and signalling should conform to ITU CCITT Recommendation E.180.*

Note.— Details of ITU CCITT Recommendation E.180 are contained in CCITT Yellow Book, Volume II — Fascicle II-2.

4.14.6 **Recommendation.—** *The numbering plan used in aeronautical speech circuit switching and signalling should consist of six digits whereby the first two digits identify the area, the third and fourth digits the control centre and the fifth and sixth digits the working position or correspondent within the control centre. Up to two additional digits may be added following the sixth digit to allow a larger number of positions within a control centre to be uniquely addressed.*

Note.— The area identifier may be used to identify either a country or a group of countries.

4.14.6.1 **Recommendation.—** *It should not be necessary to dial the area identifier code on calls between stations sharing a common area identifier.*

CHAPTER 5. SURVIVAL RADIO EQUIPMENT

Note.— Requirements for the carriage of survival radio equipment are contained in Annex 6 and specifications for the frequencies to be employed are contained in Part II of this Annex.

5.1 Specification for VHF survival radio equipment operating on 121.5 MHz and 243 MHz

5.1.1 Technical characteristics

5.1.1.1 Survival radio equipment shall operate on 121.5 MHz and 243 MHz. The frequency tolerance shall not exceed plus or minus 0.005 per cent.

Note.— Where separate equipments are provided, each capable of operation on only one of these frequencies, the two separate equipments are considered as one equipment for the purpose of complying with the appropriate Standard of Annex 6.

5.1.1.2 The emission from the survival radio equipment shall be vertically polarized and omnidirectional in the horizontal plane.

5.1.1.3 Over a period of twenty-four hours of continuous operation, the mean power radiated shall at no time be less than 100 mW.

5.1.1.4 The type of emission shall be A2A. A3E emission shall be permitted in addition to A2A.

5.1.1.5 The duration of interruption of the emission on either frequency, if any, shall be such that it will not prejudice precise location of the survival radio equipment by the homing equipment installed in the search craft.

5.1.1.6 The carrier shall be amplitude modulated at a modulation factor of at least 0.85.

5.1.1.7 The emission shall have a distinctive audio characteristic.

5.1.1.7.1 **Recommendation.—** *The distinctive audio characteristic should be achieved by modulating the carrier by an audio frequency sweeping downwards over a range of not less than 700 Hz within the range of 1 600 Hz to 300 Hz, with a repetition rate of between two and three sweeps per second.*

CHAPTER 6. EMERGENCY LOCATION BEACON — AIRCRAFT (ELBA) FOR SEARCH AND RESCUE

Note.— A Recommended Practice regarding the carriage of emergency location beacons — aircraft for search and rescue is contained in Annex 6, Part II, and specifications for the radio frequencies to be employed are contained in Part II, 2.3, of this Annex.

6.1 Specification for VHF emergency location beacons — aircraft for search and rescue operating on 121.5 MHz and 243 MHz

6.1.1 Technical characteristics

6.1.1.1 Emergency location beacons — aircraft (ELBA) shall operate on 121.5 MHz and 243 MHz. The frequency tolerance shall not exceed plus or minus 0.005 per cent.

6.1.1.2 The emission from a beacon under normal conditions and attitudes of the antenna shall be vertically polarized and essentially omnidirectional in the horizontal plane.

6.1.1.3 Over a period of forty-eight hours of continuous operation, at an operating temperature of minus 20°C, the equivalent isotropically radiated peak envelope power shall at no time be less than 75 mW on each frequency.

Note.— The term "equivalent isotropically radiated peak envelope power" used above is a combination of the appropriate definitions in the Radio Regulations 151 and 155, Peak Envelope *and* Equivalent Isotropically Radiated Powers (e.i.r.p.) *respectively.*

6.1.1.4 The type of emission shall be A2. Any other type of modulation that meets the requirements of 6.1.1.5, 6.1.1.6 and 6.1.1.7 below may be used provided that it will not prejudice precise location of the beacon by homing equipment.

6.1.1.5 The carriers shall be amplitude modulated at a modulation factor of at least 0.85.

6.1.1.6 The modulation applied to the carriers shall have a minimum duty cycle of 33 per cent.

6.1.1.7 The emission shall have a distinctive audio characteristic achieved by amplitude modulating the carriers with an audio frequency sweeping downward over a range of not less than 700 Hz within the range 1 600 Hz to 300 Hz and with a sweep repetition rate of between 2 Hz and 4 Hz.

APPENDIX A TO PART I.— MICROWAVE LANDING SYSTEM (MLS) CHARACTERISTICS

Table A-1.— Preamble timing* *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Carrier acquisition (CW transmission)	0	0
Receiver reference time code		
$I_1 = 1$	13	0.832
$I_2 = 1$	14	0.896
$I_3 = 1$	15	0.960
$I_4 = 0$	16	1.024
$I_5 = 1$	17	1.088**
Function identification		
I_6	18	1.152
I_7	19	1.216
I_8	20	1.280
I_9 (see 3.11.4.4.3.3)	21	1.344
I_{10}	22	1.408
I_{11}	23	1.472
I_{12}	24	1.536
End preamble	25	1.600

* Applies to all functions transmitted.
** Reference time for receiver synchronization for all function timing.

Table A-2.— Approach azimuth function timing *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Preamble	0	0
Morse Code	25	1.600
Antenna select	26	1.664
Rear OCI	32	2.048
Left OCI	34	2.176
Right OCI	36	2.304
TO test	38	2.432
TO scan*	40	2.560
Pause		8.760
Midscan point		9.060
FRO scan*		9.360
FRO test		15.560
End function (airborne)		15.688
End guard time; end function (ground)		15.900

* The actual commencement and completion of the TO and the FRO scan transmissions are dependent on the amount of proportional guidance provided. The time slots provided will accommodate a maximum scan of plus or minus 62.0 degrees. Scan timing shall be compatible with accuracy requirements.

Table A-3.— High rate approach azimuth and back azimuth function timing *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Preamble	0	0
Morse Code	25	1.600
Antenna select	26	1.664
Rear OCI	32	2.048
Left OCI	34	2.176
Right OCI	36	2.304
TO test	38	2.432
TO scan*	40	2.560
Pause		6.760
Midscan point		7.060
FRO scan*		7.360
FRO test pulse		11.560
End function (airborne)		11.688
End guard time; end function (ground)		11.900

* The actual commencement and completion of the TO and FRO scan transmissions are dependent upon the amount of proportional guidance provided. The time slots provided will accommodate a maximum scan of plus or minus 42.0 degrees. Scan timing shall be compatible with accuracy requirements.

Table A-4.— Approach elevation function timing *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Preamble	0	0
Processor pause	25	1.600
OCI	27	1.728
TO scan*	29	1.856
Pause		3.406
Midscan point		3.606
FRO scan*		3.806
End function (airborne)		5.356
End guard time; end function (ground)		5.600

* The actual commencement and completion of the TO and FRO scan transmissions are dependent upon the amount of proportional guidance provided. The time slots provided will accommodate a maximum scan of minus 1.5 degrees to plus 29.5 degrees. Scan timing shall be compatible with accuracy requirements.

Table A-5.— Flare function timing *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Preamble	0	0
Processor pause	25	1.600
TO scan*	29	1.856
Pause		3.056
Midscan point		3.456
FRO scan*		3.856
End function (airborne)		5.056
End guard time; end function (ground)		5.300

* The actual commencement and completion of the TO and the FRO scan transmissions are dependent upon the amount of proportional guidance provided. The time slots provided will accommodate a maximum scan of minus 2.0 degrees to plus 10.0 degrees. Scan timing shall be compatible with accuracy requirements.

Table A-6.— Basic data function timing *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Preamble	0	0
Data transmission (Bits $I_{13} - I_{30}$)	25	1.600
Parity transmission (Bits $I_{31} - I_{32}$)	43	2.752
End function (airborne)	45	2.880
End guard time; end function (ground)		3.100

Table A-7.— Basic data *(see 3.11.4.3.3)*

Word	Data content	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
1	PREAMBLE	0.4	12			$I_1 - I_{12}$
	Approach azimuth to threshold distance		6	0 m to 6 300 m	100 m	$I_{13} - I_{18}$
	Approach azimuth proportional coverage limit		5	−10° to −60°	2°	$I_{19} - I_{23}$
	Approach azimuth proportional coverage limit		5	+10° to +60°	2°	$I_{24} - I_{28}$
	Clearance signal type		1	see Note 9		I_{29}
	SPARE		1			I_{30}
	PARITY		2	see Note 1		$I_{31} - I_{32}$
2	PREAMBLE	0.16	12			$I_1 - I_{12}$
	Ground equipment performance level		2	see Note 2		$I_{13} - I_{14}$
	Minimum glide-path		6	2° – 8.2°	0.1°	$I_{15} - I_{20}$
	Back azimuth next function		1	see Note 3		I_{21}
	SPARE		7	see Note 6		$I_{22} - I_{28}$
	DME status		2	see Note 2		$I_{29} - I_{30}$
	PARITY		2	see Note 1		$I_{31} - I_{32}$

Table A-7.— Basic data *(cont.)*

Word	Data content	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
3	PREAMBLE	10	12			$I_1 - I_{12}$
	Approach azimuth beamwidth		3	0.5° to 4°	0.5°	$I_{13} - I_{15}$
	Approach elevation beamwidth		3	0.5° to 2.5°	0.5°	$I_{16} - I_{18}$
	Flare elevation beamwidth		2	0.5° to 1°	0.25°	$I_{19} - I_{20}$
	Approach azimuth sector guidance alert					
	−60° to −20°		3	1° to 8°	1°	$I_{21} - I_{23}$
	−20° to −5°		2	1° to 4°	1°	$I_{24} - I_{25}$
	+20° to +5°		2	1° to 4°	1°	$I_{26} - I_{27}$
	+60° to +20°		3	1° to 8°	1°	$I_{28} - I_{30}$
	PARITY		2	see Note 1		$I_{31} - I_{32}$
4	PREAMBLE	10	12			$I_1 - I_{12}$
	DM distance		12	−8 000 m to +8 000 m see Note 7	4 m	$I_{13} - I_{24}$
	DME offset		6	−155 m to +155 m see Note 7	5 m	$I_{25} - I_{30}$
	PARITY		2	see Note 1		$I_{31} - I_{32}$
5	PREAMBLE	10	12			$I_1 - I_{12}$
	Approach azimuth antenna offset		7	−126 m to +126 m see Note 7	2 m	$I_{13} - I_{19}$
	DME or DME/P		1	DME = 0 DME/P = 1		I_{20}
	DME channel		9	see Note 8		$I_{21} - I_{29}$
	SPARE		1			I_{30}
	PARITY		2	see Note 1		$I_{31} - I_{32}$
6	PREAMBLE	10	12			$I_1 - I_{12}$
	MLS ground subsystem identification (see Note 4)			Letters A to Z		
	Character 2		6			$I_{13} - I_{18}$
	Character 3		6			$I_{19} - I_{24}$
	Character 4		6			$I_{25} - I_{30}$
	PARITY		2	see Note 1		$I_{31} - I_{32}$

Table A-7.— Basic data *(cont.)*

Word	Data content	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
7	PREAMBLE	1	12	see Note 5		$I_1 - I_{12}$
	Ground equipment performance level		2	see Note 2		$I_{13} - I_{14}$
	Back azimuth antenna distance		5	0 m to 3 100 m	100 m	$I_{15} - I_{19}$
	Back azimuth proportional coverage limit		4	−10° to −40°	2°	$I_{20} - I_{23}$
	Back azimuth proportional coverage limit		4	+10° to +40°	2°	$I_{24} - I_{27}$
	Back azimuth beamwidth		2	1° to 4°	1°	$I_{28} - I_{29}$
	SPARE		1			I_{30}
	PARITY		2	see Note 1		$I_{31} - I_{32}$
8	PREAMBLE	10	12			$I_1 - I_{12}$
	Elevation antenna height		6	−1 m to +5.2 m see Note 7	0.2 m	$I_{13} - I_{18}$
	Elevation antenna offset		5	−150 m to +150 m see Note 7	10 m	$I_{19} - I_{23}$
	MLS datum point to threshold distance		7	0 m to 630 m	5 m	$I_{24} - I_{30}$
	PARITY		2	see Note 1		$I_{31} - I_{32}$

NOTES

NOTE 1 Parity checks that there is an even number of ones in Bits I_{13} to I_{30} and obeys the equations:

$$I_{13} + I_{14} \quad \ldots \quad + I_{29} + I_{30} + I_{31} = \text{EVEN}$$

$$I_{14} + I_{16} + I_{18} \quad \ldots \quad + I_{28} + I_{30} + I_{32} = \text{EVEN}$$

NOTE 2 Coding not yet defined.

NOTE 3 Code for I_{21} is:

0 = No back azimuth transmission
1 = Back azimuth transmission to follow

NOTE 4 Data word 6 is transmitted for both approach azimuth and back azimuth coverages alternately and at the 10-second maximum time between transmissions for each coverage sector, if back azimuth guidance is provided.

NOTE 5 Data word 7 is transmitted from the back azimuth equipment.

NOTE 6 These bits are reserved for future applications requiring high transmission rates.

Table A-7.— Basic data *(cont.)*

NOTE 7 The convention for the coding of negative numbers is as follows:

— MSB is the sign bit:
0 = +
1 = −

— Other bits represent the absolute value.

The convention for the antenna location is as follows: as viewed from the MLS approach reference datum looking toward the MLS datum point, a positive number shall represent a location to the right of the runway centre line (lateral offset) or above the runway (vertical offset), or towards the stop end of the runway (longitudinal distance).

NOTE 8 Coding not yet defined. Nine bits provide the capability to encode frequency and mode separately.

NOTE 9 Code for I_{29} is:
0 = pulse clearance signal
1 = scanning clearance signal

Table A-8.— Auxiliary data function timing *(see 3.11.4.3.4)*

Event	Event time slot begins at	
	15.625 kHz Clock pulse (number)	Time (milli-seconds)
Preamble	0	0
Address transmission (Bits I_{13} −I_{20})	25	1.600
Data transmission (Bits I_{21} −I_{72})	33	2.112
Parity transmission (Bits I_{73} −I_{76})	85	5.440
End function (airborne)	89	5.696
End guard time; end function (ground)		5.900

PART II — RADIO FREQUENCIES

CHAPTER 1. DEFINITIONS

When the following terms are used in this Part of the Annex, they have the following meanings:

Alternative means of communication. A means of communication provided with equal status, and in addition to the primary means.

Double channel simplex. Simplex using two frequency channels, one in each direction.

Note.— This method was sometimes referred to as cross-band.

Duplex. A method in which telecommunication between two stations can take place in both directions simultaneously.

Frequency channel. A continuous portion of the frequency spectrum appropriate for a transmission utilizing a specified class of emission.

Note.— The classification of emissions and information relevant to the portion of the frequency spectrum appropriate for a given type of transmission (bandwidths) are specified in the Radio Regulations, Article 4 RR 264 to RR 273 inclusive.

Offset frequency simplex. A variation of single channel simplex wherein telecommunication between two stations is effected by using in each direction frequencies that are intentionally slightly different but contained within a portion of the spectrum alloted for the operation.

Operational control communications. Communications required for the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of a flight.

Note.— Such communications are normally required for the exchange of messages between aircraft and aircraft operating agencies.

Primary means of communication. The means of communication to be adopted normally by aircraft and ground stations as a first choice where alternative means of communication exist.

Simplex. A method in which telecommunication between two stations takes place in one direction at a time.

Note.— In application to the Aeronautical Mobile Service, this method may be subdivided as follows:

a) single channel simplex;

b) double channel simplex;

c) offset frequency simplex.

Single channel simplex. Simplex using the same frequency channel in each direction.

CHAPTER 2. DISTRESS FREQUENCIES

Introduction

The Standards and Recommended Practices relating to radio frequencies for distress communications take into account certain procedures that have been adopted by ICAO and also certain provisions made by the ITU in its Radio Regulations.

The ICAO Communication Procedures require that an aircraft in distress when it is airborne should use the frequency in use for normal communications with aeronautical stations at the time. However, it is recognized that, after an aircraft has crashed or ditched, there is a need for designating a particular frequency or frequencies to be used in order that uniformity may be attained on a world-wide basis, and so that a guard may be maintained or set up by as many stations as possible including direction-finding stations, and stations of the Maritime Mobile Service.

The frequency 2 182 kHz also offers possibilities for communication between aircraft and stations of the Maritime Mobile Service. The current Radio Regulations specify (RR 2973) that the frequency 2 182 kHz is the international distress frequency for radiotelephony to be used for that purpose by ship, aircraft and survival craft stations using frequencies in the authorized bands between 1 605 kHz and 4 000 kHz when requesting assistance from the maritime service.

Similarly, the frequency 500 kHz is the international distress frequency for radiotelegraphy to be used for that purpose by ship, aircraft and survival craft stations using frequencies in the bands between 405 kHz and 535 kHz when requesting assistance from the maritime service (RR 2970).

With respect to survival craft stations, the Radio Regulations provide for the use of the frequency(ies) 500 kHz, 8 364 kHz, 2 182 kHz, 121.5 MHz and 243 MHz, if the survival craft is capable of operating in the bands between 405-535 kHz, 4 000-27 500 kHz, 1 605-2 850 kHz, 117.975-136 MHz and 235-328.6 MHz respectively (RR 3001-3008).

2.1 Frequencies for survival radio equipment

2.1.1 Survival radio equipment carried in compliance with Standards 6.5.3 b) and 6.6 of Annex 6, Part I, and 6.3.3 b) 2) and 6.4 of Annex 6, Part II, shall operate on 121.5 MHz and 243 MHz, except that, where the whole of a proposed flight is within an area where, for SAR purposes, only one of these frequencies is required, the use of that single frequency may be specifically authorized, if so agreed by the authorities responsible for SAR in the area concerned.

2.1.2 Until 1 January 1969, survival radio equipments using frequencies selected from 500 kHz, 2 182 kHz, 8 364 kHz, 121.5 MHz and 243 MHz shall be permitted.

Note.— Requirements respecting the carriage of radio equipment for survival purposes are contained in Annex 6, Parts I and II.

2.2 Search and rescue frequencies

2.2.1 Where there is a requirement for the use of high frequencies for search and rescue scene of action co-ordination purposes, the frequencies 3 023 kHz and 5 680 kHz shall be employed.

2.2.2 **Recommendation.**— *Where specific frequencies are required for communication between rescue co-ordination centres and aircraft engaged in search and rescue operations, they should be selected regionally from the appropriate aeronautical mobile frequency bands in the light of the nature of the provisions made for the establishment of search and rescue aircraft.*

Note.— Where civil commercial aircraft take part in search and rescue operations, they will normally communicate on the appropriate en-route channels with the flight information centre associated with the rescue co-ordination centre concerned.

2.3 Frequencies for emergency location beacons — aircraft (ELBA) for search and rescue

2.3.1 Emergency location beacons — aircraft for search and rescue carried in accordance with provisions of Annex 6, Part II, and conforming with the specifications of this Annex, Part I, Chapter 6, shall operate on 121.5 MHz and 243 MHz, except that, where the whole of a proposed flight is within an area where, for search and rescue purposes, only one of these frequencies is required, the use of that single frequency may be specifically authorized, if so agreed by the authorities responsible for search and rescue in the area concerned.

CHAPTER 3. UTILIZATION OF FREQUENCIES BELOW 30 MHz

Introduction

High frequency bands allocated to the Aeronautical Mobile (R) Service

The frequency bands between 2.8 MHz and 22 MHz allocated to the Aeronautical Mobile (R) Service are given in Article 8 of the Radio Regulations. The utilization of these bands must be in accordance with the relevant provisions of the Radio Regulations. Prior to 1 September 1979, the provisions are contained in the Final Acts of the ITU Extraordinary Administrative Radio Conference (Geneva 1966). On 1 September 1979, revised provisions came into force, details of which are contained in the Final Acts of the World Administrative Radio Conference for the Aeronautical Mobile (R) Service (Geneva 1978) and Appendix 27 Aer2 to the Radio Regulations, except the Frequency Allotment Plan which entered into force at 0001 hours UTC, 1 February 1983. In the utilization of these bands, States' attention is drawn to the possibility of harmful radio interference from non-aeronautical sources of radio frequency energy and the need to take appropriate measures to minimize its effects.

3.1 Method of operations

3.1.1 In the Aeronautical Mobile Service, single channel simplex shall be used in radiotelephone communications utilizing radio frequencies below 30 MHz in the bands allocated exclusively to the Aeronautical Mobile (R) Service.

3.1.2 Assignment of single sideband channels

3.1.2.1 Single sideband channels shall be assigned in accordance with Part I, 4.11.1.3 and 4.11.1.4.

3.1.2.2 Until 1 February 1983 it shall be permissible to use channels in the new Plan provided that no harmful interference occurs to users of channels in the present Plan. For the operational use of the channels concerned administrations shall take into account the provisions of 27/20 of Appendix 27 Aer2 of the Radio Regulations.

3.1.2.3 **Recommendation.**— *The use of aeronautical mobile (R) frequencies below 30 MHz for international operations should be co-ordinated as specified in Appendix 27 Aer2 of the Radio Regulations as follows:*

27/20 The International Civil Aviation Organization (ICAO) co-ordinates radiocommunications of the Aeronautical Mobile (R) Service with international aeronautical operations and this Organization should be consulted in all appropriate cases in the operational use of the frequencies in the Plan.

3.1.2.4 **Recommendation.**— *Where international operating requirements for HF communications cannot be satisfied by the allotments in the table at Nos. 27/195 to 27/207 in Appendix 27 EARC, an appropriate frequency should be assigned as specified in Appendix 27 Aer2 of the Radio Regulations as follows:*

27/21 It is recognized that not all the sharing possibilities have been exhausted in the Allotment Plan contained in this Appendix. Therefore, in order to satisfy particular operational requirements which are not otherwise met by this Allotment Plan, administrations may assign frequencies from the aeronautical mobile (R) bands in areas other than those to which they are alloted in this Plan. However, the use of the frequencies so assigned must not reduce the protection to the same frequencies in the areas where they are allotted by the Plan below that determined by the application of the procedure defined in Part I, Section II B of this Appendix.

Note.— Part I, Section II B of Appendix 27 Aer2 relates to Interference Range Contours, and application of the procedure results in a protection ratio of 15 dB.

27/22 When necessary to satisfy the needs of international air operations administrations may adapt the allotment procedure for the assignment of aeronautical mobile (R) frequencies, which assignments shall then be the subject of prior agreement between administrations affected.

27/23 The co-ordination described in No. 27/20 shall be effected where appropriate and desirable for the efficient utilization of the frequencies in question, and especially when the procedures of No. 27/22 are unsatisfactory.

3.1.2.5 The use of classes of emission J7B and J9B shall be subject to the following provisions of Appendix 27 Aer2:

27/11 For radiotelephone emissions the audio frequencies will be limited to between 300 and 2 700 Hz and the occupied bandwidth of other authorized emissions will not exceed the upper limit of J3E emissions. In specifying these limits, however, no restriction in their extension is implied in so far as emissions other than J3E are concerned, provided that the limits of unwanted emissions are met (see Nos. 27/66B and 27/66C).

27/11B On account of the possibility of interference, a given channel should not be used in the same allotment area for radiotelephony and data transmissions.

27/12 The use of channels derived from the frequencies indicated in 27/16 for the various classes of emissions other than J3E and H2B will be subject to special arrangements by the administrations concerned and affected in order to avoid harmful interference which may result from the simultaneous use of the same channel for several classes of emission.

3.1.3 Assignment of frequencies for aeronautical operational control communications

3.1.3.1 World-wide frequencies for aeronautical operational control communications are required to enable aircraft operating agencies to meet the obligations prescribed in Annex 6, Part I. Assignment of these frequencies shall be in accordance with the following provisions of Appendix 27 Aer2:

27/8A A world-wide allotment area is one in which frequencies are allotted to provide long distance communications between an aeronautical station within that allotment area and aircraft operating anywhere in the world.

27/8A.1 The type of communication referred to in 27/8A may be regulated by Administrations.

27/194A The world-wide frequency allotments appearing in the tables at No. 27/189 and Nos. 27/195 to 27/207, except for carrier (reference) frequencies 3 023 kHz and 5 680 kHz, are reserved for assignment by administrations to stations operating under authority granted by the administration concerned for the purpose of serving one or more aircraft operating agencies. Such assignments are to provide communications between an appropriate aeronautical station and an aircraft station anywhere in the world for exercising control over regularity of flight and for safety of aircraft. World-wide frequencies are not to be assigned by administrations for MWARA, RDARA and VOLMET purposes. Where the operational area of an aircraft lies wholly within a RDARA or sub-RDARA boundary, frequencies allotted to those RDARAs and sub-RDARAs shall be used.

Note 1.— Tables 27/189 and 27/195 to 27/207 appearing in Appendix 27 Aer2 to the Radio Regulations refer to, respectively, the Frequency Allotment Plan, listing frequencies by areas, and the Frequency Allotment Plan, listing frequencies in numerical order.

Note 2.— Guidance material on the assignment of world-wide frequencies is contained in Attachment C to Part II to this Annex.

3.2 NDB frequency management

3.2.1 **Recommendation.**— *NDB frequency management should take into account the following:*

a) the interference protection required at the edge of the rated coverage;

b) the application of the figures shown for typical ADF equipments;

c) the geographical spacings and the respective rated coverages;

d) the possibility of interference from spurious radiations generated by non-aeronautical sources (e.g. electric power services, power line communication systems, industrial radiations, etc.).

Note 1.— Guidance material to assist in determining the application of the foregoing is given in Attachment B to Part II.

Note 2.— Attention is drawn to the fact that some portions of the bands available for aeronautical beacons are shared with other services.

3.2.2 **Recommendation.**— *To alleviate frequency congestion problems, at locations where two separate ILS facilities serve opposite ends of a single runway, the assignment of a common frequency to both of the outer locators should be permitted, and the assignment of a common frequency to both of the inner locators should be permitted, provided that:*

a) the operational circumstances permit;

b) each locator is assigned a different identification signal;

c) arrangements are made whereby locators using the same frequency cannot radiate simultaneously.

Note.— The Standard in Part I, 3.4.4.4, specifies the equipment arrangements to be made.

CHAPTER 4. UTILIZATION OF FREQUENCIES ABOVE 30 MHz

4.1 Utilization in the band 117.975-137 MHz

Introduction

The band 118-132 MHz was allocated in 1947 by the Atlantic City ITU Radio Conference, and again in 1959 by the Geneva Conference, but with extension downwards to 117.975 MHz, for the exclusive use by the Aeronautical Mobile (R) Service. This Chapter of Annex 10 deals with Standards and Recommended Practices relating to this band and includes matters pertaining to the selection of particular frequencies for various aeronautical purposes. These Standards are introduced by the following preface, which sets out the principles upon which the utilization of VHF on a world-wide basis with due regard to economy has been planned.

ITU Radio Conferences subsequent to 1947 also made provisions for the use of the band 132-136 MHz for the Aeronautical Mobile (R) Service under conditions which vary for the different ITU Regions, countries or combination of countries. The utilization of this band has been included in the Allotment Table in this Chapter; however, it should be kept in mind that the use of frequencies of the band 132-136 MHz must take account of the conditions contained in the notes against this band in the ITU Allocation Table. The ITU Radio Conference (1979) made provisions for the use of the band 136-137 MHz by the Aeronautical Mobile (R) Service, subject to conditions of No. 595 of the Radio Regulations. In the utilization of these bands, States' attention is drawn to the possibility of harmful radio interference from non-aeronautical sources of radio frequency energy and the need to take appropriate measures to minimize its effects.

Preface

The utilization of VHF on a world-wide basis with due regard to economy and practicability requires a plan that will take into account:

a) the need for an orderly evolution towards improved operation and the required degree of world-wide standardization;

b) the desirability of providing for an economic transition from present utilization to optimum utilization of the frequencies available, taking into account the maximum possible utilization of existing equipment;

c) the need to provide for co-ordination between international and national utilization so as to ensure mutual protection from interference;

d) the need for providing a framework for the integrated development of Regional Plans;

e) the desirability of incorporating in any group of frequencies to be used those now in use for international air services;

f) the need for keeping the total number of frequencies and their grouping in appropriate relation to the airborne equipment known to be widely used by international air services;

g) a requirement for the provision of a single frequency that may be used for emergency purposes on a world-wide basis and, also, in certain regions, for another frequency that may be used as a common frequency for special purposes;

h) the need for providing sufficient flexibility to allow for the differences in application necessitated by regional conditions.

4.1.1 General allotment of frequency band 117.975-137 MHz

Note.— The plan includes a general Allotment Table that subdivides the complete band 117.975-137 MHz, the chief subdivisions being the bands of frequencies allocated to both national and international services, and the bands allocated to national services. Observance of this general subdivision should keep to a minimum the problem of co-ordinating national and international application.

The block allotment of the frequency band 117.975-137 MHz shall be as shown in Table 4-1.

In the case of the new band 136-137 MHz, international applications have not yet been agreed, and these frequencies should be brought into use on a regional basis where and in the manner required.

4.1.2 Frequency separation and limits of assignable frequencies

4.1.2.1 The minimum separation between assignable frequencies in the Aeronautical Mobile (R) Service shall be 25 kHz.

Note.— It is recognized that, in some regions or areas, 100 kHz or 50 kHz channel spacing may provide an adequate number of frequencies suitably related to international and national air services and that equipment designed specifically for 100 kHz or 50 kHz channel spacing will remain adequate for services operating within such regions or areas.

4.1.2.2 Until at least 1 January 1995, equipment specifically designed for 25 kHz channel spacing shall be safeguarded

Table 4.1 Allotment table

Block allotment of frequencies (MHz)	*World-wide utilization*	*Remarks*
a) 118 to 121.4 inclusive	International and National Aeronautical Mobile Services	Specific international allotments will be determined in the light of regional agreement. National assignments are covered by the provisions in 4.1.5.9 below.
b) 121.5	Emergency frequency	In order to provide a guard band for the protection of the aeronautical emergency frequency, the nearest assignable frequencies on either side of 121.5 MHz are 121.4 MHz and 121.6 MHz, except that by regional agreement it may be decided that the nearest assignable frequencies are 121.3 MHz and 121.7 MHz.
c) 121.6 to 121.975 inclusive	International and National aerodrome surface communications	Reserved for ground movement, pre-flight checking, air traffic services clearances, and associated operations.
d) 122 to 123.05 inclusive	National Aeronautical Mobile Services	Reserved for national allotments.
e) 123.1	Auxiliary frequency SAR	See 4.1.4.1 below.
f) 123.15 to 123.675	National Aeronautical Mobile Services	Reserved for national allotments.
g) 123.7 to 129.675 inclusive	International and National Aeronautical Mobile Services	Specific international allotments will be determined in the light of regional agreement. National assignments are covered by the provisions in 4.1.5.9 below.
h) 129.7 to 130.875 inclusive	National Aeronautical Mobile Services	Reserved for national allotments but may be used in whole or in part, subject to regional agreement, to meet the requirements mentioned in 4.1.8.1.3 below.
i) 130.9 to 135.975 inclusive	International and National Aeronautical Mobile Services	Specific international allotments will be determined in the light of regional agreement. National assignments are covered by the provisions in 4.1.5.9 below. (See remark in the Introduction to 4.1 above regarding the band 132-136 MHz.)

with respect to its suitability for the Aeronautical Mobile (R) Service.

4.1.2.3 In the band 117.975-137 MHz, the lowest assignable frequency shall be 118 MHz and the highest 136.975 MHz.

4.1.3 Frequencies used for particular functions

4.1.3.1 *Emergency channel*

4.1.3.1.1 The emergency channel (121.5 MHz) shall be used only for genuine emergency purposes, as broadly outlined in the following:

a) to provide a clear channel between aircraft in distress or emergency and a ground station when the normal channels are being utilized for other aircraft;

b) to provide a VHF communication channel between aircraft and aerodromes, not normally used by international air services, in case of an emergency condition arising;

c) to provide a common VHF communication channel between aircraft, either civil or military, and between such aircraft, and surface services, involved in common search and rescue operations, prior to changing when necessary to the appropriate frequency;

d) to provide air-ground communication with aircraft when airborne equipment failure prevents the use of the regular channels;

e) to provide a frequency channel for the operation of survival radio equipment or emergency location beacon — aircraft (ELBA), and for communication between survival craft and aircraft engaged in search and rescue operations;

f) to provide a common VHF channel for communication between civil aircraft and military aircraft or intercept control units in the event of interception of the civil aircraft.

Note 1.— The use of the frequency 121.5 MHz for the purpose outlined in c) above is to be avoided if it interferes in any way with the efficient handling of distress traffic.

Note 2.— The current Radio Regulations make provisions that the aeronautical emergency frequency 121.5 MHz may also be used by mobile stations of the Maritime Mobile Service, using A3E emission to communicate on this frequency for safety purposes with stations of the Aeronautical Mobile Service (RR 593, 2990 and 2991).

4.1.3.1.2 The frequency of 121.5 MHz shall be provided at:

a) all area control centres and flight information centres; and

b) aerodrome control towers and approach control offices serving international aerodromes and international alternate aerodromes,

where the provision of that frequency is considered necessary to ensure immediate reception of distress calls or to serve the purposes specified in 4.1.3.1.1 above.

4.1.3.1.3 **Recommendation.—** *The frequency of 121.5 MHz should be provided at any additional locations where such provision is considered necessary to ensure immediate reception of distress calls or to serve the purposes specified in 4.1.3.1.1 above.*

4.1.3.1.4 The emergency channel shall be guarded continuously during the hours of service of the units at which it is installed.

4.1.3.1.5 The emergency channel shall be guarded on a single channel simplex operation basis.

4.1.3.2 *Air-to-air communications channel*

4.1.3.2.1 Subject to regional air navigation agreement, an air-to-air VHF communications channel shall be designated to enable aircraft engaged in flights over remote and oceanic areas out of range of VHF ground stations to exchange necessary operational information and to facilitate the resolution of operational problems.

Note.— The assignment of the frequency to be used for the VHF air-to-air communications channel is intended to be coordinated whenever necessary between adjacent regions to ensure the most efficient and safe utilization of VHF frequencies.

4.1.4 Auxiliary frequencies for search and rescue operations

4.1.4.1 Where a requirement is established for the use of a frequency auxiliary to 121.5 MHz, as described in 4.1.3.1.1 c) above, the frequency 123.1 MHz shall be used.

4.1.5 Provisions concerning the deployment of VHF frequencies and the avoidance of harmful interference

4.1.5.1 In the case of those VHF facilities providing service up to the radio horizon, the geographical separation between facilities working on the same frequency shall, except where there is an operational requirement for the use of common frequencies for groups of facilities, be such that points at the protection heights and at the limit of the functional service range of each facility are separated by distances not less than the sum of distances from each of the points to its associated radio horizon.

4.1.5.2 In the case of those VHF facilities providing service beyond the radio horizon, except where there is an operational requirement for the use of common frequencies for groups of facilities, planning for co-channel operations shall be such that points at the protection heights and at the limits of the functional service area of each facility are separated by distances not less than the sum of distances from each point to its associated radio horizon.

Note 1.— The distance to the radio horizon from a station in an aircraft is normally given by the formula:

$$D = K\sqrt{h}$$

where D = *distance in nautical miles;*

h = *height of the aircraft station above earth;*

K = *(corresponding to an effective earth's radius of 4/3 of the actual radius)*

= *2.22 when* h *is expressed in metres; and*

= *1.23 when* h *is expressed in feet.*

Note 2.— In calculating the radio line-of-sight distance between a ground station and an aircraft station, the distance from the radio horizon of the aircraft station computed from Note 1 above must be added to the distance from the radio horizon of the ground station. In calculating the latter the same formula is employed, taking for h *the height of the ground station transmitting antenna.*

Note 3.— The criterion contained in 4.1.5.2 above is applicable in establishing minimum geographical separation between VHF facilities, with the object of avoiding co-channel air-to-air interference. Guidance material relating to the establishment of separation distances between ground stations and between aircraft and ground stations for co-channel operations is contained in Section 3 of Attachment A to Part II. Guidance material relating to adjacent channel frequency deployment is contained in Section 2 of Attachment A to Part II.

Note 4.— Guidance material on the interpretation of 4.1.5.1 and 4.1.5.2 above is contained in Attachment A to Part II.

4.1.5.3 The geographical separation between facilities working on adjacent channels shall be such that points at the protection heights and at the limit of the functional service range of each facility are separated by a distance sufficient to ensure operations free from harmful interference.

Note.— Guidance material covering separation distances and related system characteristics is contained in Attachment A to Part II.

4.1.5.4 The protection height shall be a height above a specified datum associated with a particular facility, such that below it harmful interference is improbable.

4.1.5.5 The protection height to be applied to functions or to specific facilities shall be determined regionally, taking into consideration the following factors:

a) the nature of the service to be provided;

b) the air traffic pattern involved;

c) the distribution of communication traffic;

d) the availability of frequency channels in airborne equipment;

e) probable future developments.

4.1.5.6 **Recommendation.—** *Where the protection heights determined are less than those operationally desirable, separation between facilities operating on the same frequency should not be less than that necessary to ensure that an aircraft at the limit of the functional service range and the operationally desirable protection height of one facility does not come above the radio horizon with respect to adjacent facilities.*

Note.— The effect of this recommendation is to establish a geographical separation distance below which harmful interference is probable.

4.1.5.7 The geographical separation between VHF VOLMET stations shall be determined regionally and, generally, shall be such that operations free from harmful interference are secured at the highest altitude flown by aircraft in the area concerned.

Note.— Guidance material on the interpretation of 4.1.5.7 above is contained in Attachment A to Part II.

4.1.5.8 Frequencies in the aeronautical mobile VHF band used for national services, unless world-wide or regionally allotted to this specific purpose, shall be so deployed that minimum interference is caused to facilities for the international air services in this band.

4.1.5.9 **Recommendation.—** *The problem of inter-State interference on frequencies allotted world-wide or on a regional basis to national services, should be resolved by consultation between the Administrations concerned.*

4.1.5.10 The communication coverage provided by a VHF ground transmitter shall, in order to avoid harmful interference to other stations, be kept to the minimum consistent with the operational requirement for the function.

4.1.5.11 **Recommendation.—** *For ground VHF facilities which provide service beyond the radio horizon, any spurious or harmonic radiation outside the band plus or minus 250 kHz from the assigned carrier frequency should not exceed an effective radiated power of 1 mW in any azimuth.*

4.1.6 Equipment requirements

Note 1.— Frequency tolerances to which stations operating in the aeronautical mobile band (117.975-137 MHz) must conform are contained in Appendix 3 to the Radio Regulations. Tolerances for transmitters used for aeronautical services are not mentioned in this Annex, except in those cases where tighter tolerances than those contained in the Radio Regulations are required (e.g. the equipment specifications in Part I contain several such instances).

Note 2.— The frequency tolerance applicable to individual components of a multi-carrier or similar system will be determined by the characteristics of the specific system.

4.1.6.1 **Recommendation.—** *The antenna gain of an extended range VHF facility should preferably be such as to ensure that, beyond the limits of plus or minus 2 Φ about the centre line of the angular width Φ of the area to be served, it does not exceed 3 dB above that of a dipole. But, in any case, it should be such as to ensure freedom from harmful interference with other radio services.*

Note 1.— The actual azimuth, the angular width of the service area, and the effective radiated power would have to be taken into account in each individual case.

Note 2.— Guidance material on the interpretation of 4.1.6.1 above is contained in Attachment A to Part II.

4.1.7 Method of operation

4.1.7.1 Single channel simplex operation shall be used in the VHF band 117.975 MHz to 136 MHz at all stations providing for aircraft engaged in international air navigation.

4.1.7.2 In addition to the above, the ground-to-air voice channel associated with an ICAO standard radio navigational aid may be used, subject to regional agreement, for broadcast or communication purposes or both.

4.1.8 Plan of assignable VHF radio frequencies for use in the international aeronautical mobile service

Introduction

This plan designates the list of frequencies available for assignment, together with provision for the use by the Aeronautical Mobile (R) Service of all frequencies with a channel

spacing of 25 kHz, with the frequencies in Group A continuing to be used wherever they provide a sufficient number to meet the operational requirements.

The plan provides that the total number of frequencies required in any region would be determined regionally. The effect of this will be that frequencies assignable in a particular region may be restricted to a limited number of the frequencies in the list, the actual number being selected as outlined herein.

In order that the assignable frequencies may be co-ordinated between regions as far as practicable, the plan requires that, whenever the number of frequencies contained in Group A of 4.1.8.1.2 below is sufficient to meet the requirements in a region, the frequencies of this Group be used in the sequence commencing with 118 MHz. This ensures that all regions will have in common the frequencies used in the region requiring the least number of frequencies and, in respect to any two regions, the region with the greater number will have in use all the frequencies used by the other. Group A provides for frequency planning based on 100 kHz channel spacing.

Group B of the list at 4.1.8.1.2 below contains the frequencies in the band 117.975-132 MHz ending in 50 kHz. Together with the frequencies in Group A, they provide for frequency planning based on 50 kHz channel spacing. In Group C are listed the frequency channels in the band 132-137 MHz based upon 50 kHz channel spacing. Group D contains the frequency channels in the band 132-137 MHz ending in 25 kHz, and Group E similarly lists the frequency channels in the band 117.975-132 MHz. The utilization of the channels in Groups B, C, D and E is explained below.

Whenever the number of frequencies required in a particular region exceeds the number in Group A, frequencies may be selected from the other Groups taking into account the provisions of 4.1.8.1 below with respect to the use of channels based on 25 kHz channel spacing and, with regard to the band 132-137 MHz, the provisions of the Radio Regulations (see Introduction to 4.1 above). Although for Groups B, C, D and E a preferred order of selection is not indicated, regional planning may require a particular selection of frequencies from these Groups in order to cater for specific regional circumstances. This may apply particularly to the utilization of frequencies from the band 132-137 MHz for reasons of available airborne equipment and/or availability of particular frequency channels for the Aeronautical Mobile (R) Service. It may also be found that, in a particular region, it is desirable to select frequencies from Group B first, before selecting frequencies from Groups C, D or E.

In many regions particular frequencies have already been assigned for particular functions as, for instance, aerodrome or approach control. The plan does not make such assignments (except in respect to the emergency channel and ground service frequencies), such action being taken regionally if considered desirable.

4.1.8.1 The frequencies in the band 117.975 MHz to 136 MHz for use in the Aeronautical Mobile (R) Service shall be selected from the list in 4.1.8.1.2 below.

Note.— Frequencies between 136 and 136.975 MHz are not available for international use before 1990.

4.1.8.1.1 When the number of frequencies required in a particular region does not exceed the number of frequencies contained in Group A of 4.1.8.1.2 below, the frequencies to be used shall be selected in sequence, in so far as practicable, from those of Group A of 4.1.8.1.2 below.

4.1.8.1.2 *List of assignable frequencies*

The list of assignable frequencies is shown on the following pages.

4.1.8.1.3 **Recommendation.**— *Frequencies for operational control communications may be required to enable aircraft operating agencies to meet the obligations prescribed in Annex 6, Part I, in which case they should be selected from the bands 128.825-132.025 MHz. These frequencies should be chosen, in so far as practicable, from the upper end of the band and in sequential order.*

Note.— It is recognized that the assignment of such frequencies and the licensing of the operation of the related facilities are matters for national determination. However, in regions where a problem exists with respect to the provision of frequencies for operational control purposes, it may be advantageous if States endeavour to co-ordinate the requirements of aircraft operating agencies for such channels prior to regional meetings.

4.1.8.2 The frequencies that may be allotted for use in the Aeronautical Mobile (R) Service in a particular region shall be limited to the number determined as being necessary for operational needs in the region.

Note.— The number of frequencies required in a particular region is normally determined by the Council on the recommendations of Regional Air Navigation Meetings. The capabilities of VHF airborne equipment known to be widely used in the region will be taken into account in this determination.

4.2 Utilization in the band 108-117.975 MHz

4.2.1 The block allotment of the frequency band 108-117.975 MHz shall be as follows:

— *Band 108-111.975 MHz:*

a) ILS in accordance with 4.2.2 below and Part I, 3.1.5;

b) VOR provided that:

1) no harmful adjacent channel interference is caused to ILS;

2) only frequencies ending in either *even tenths* or *even tenths plus a twentieth* of a megahertz are used.

— *Band 111.975-117.975 MHz:* VOR

Frequency (MHz)	*Annotations*
121.5	Emergency frequency
123.1	Auxiliary frequency SAR
121.60	Reserved for aerodrome surface communications [see Table 4-1, Item c)]
121.65	
121.70	
121.75	
121.80	
121.85	
121.90	
121.95	
121.625	
121.675	
121.725	
121.775	
121.825	
121.875	
121.925	
121.975	

GROUP A

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
118.00	123.80	127.40
118.10	123.90	127.50
118.20	124.00	127.60
118.30	124.10	127.70
118.40	124.20	127.80
118.50	124.30	127.90
118.60	124.40	128.00
118.70	124.50	128.10
118.80	124.60	128.20
118.90	124.70	128.30
119.00	124.80	128.40
119.10	124.90	128.50
119.20	125.00	128.60
119.30	125.10	128.70
119.40	125.20	128.80
119.50	125.30	128.90
119.60	125.40	129.00
119.70	125.50	129.10
119.80	125.60	129.20
119.90	125.70	129.30
120.00	125.80	129.40
120.10	125.90	129.50
120.20	126.00	129.60
120.30	126.10	130.90
120.40	126.20	131.00
120.50	126.30	131.10
120.60	126.40	131.20
120.70	126.50	131.30
120.80	126.60	131.40
120.90	126.70	131.50
121.00	126.80	131.60
121.10	126.90	131.70
121.20	127.00	131.80
121.30	127.10	131.90
121.40	127.20	
123.70	127.30	

GROUP B

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
118.05	123.85	127.35
118.15	123.95	127.45
118.25	124.05	127.55
118.35	124.15	127.65
118.45	124.25	127.75
118.55	124.35	127.85
118.65	124.45	127.95
118.75	124.55	128.05
118.85	124.65	128.15
118.95	124.75	128.25
119.05	124.85	128.35
119.15	124.95	128.45
119.25	125.05	128.55
119.35	125.15	128.65
119.45	125.25	128.75
119.55	125.35	128.85
119.65	125.45	128.95
119.75	125.55	129.05
119.85	125.65	129.15
119.95	125.75	129.25
120.05	125.85	129.35
120.15	125.95	129.45
120.25	126.05	129.55
120.35	126.15	129.65
120.45	126.25	130.95
120.55	126.35	131.05
120.65	126.45	131.15
120.75	126.55	131.25
120.85	126.65	131.35
120.95	126.75	131.45
121.05	126.85	131.55
121.15	126.95	131.65
121.25	127.05	131.75
121.35	127.15	131.85
123.75	127.25	131.95

GROUP C

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
132.00	132.95	133.90
132.05	133.00	133.95
132.10	133.05	134.00
132.15	133.10	134.05
132.20	133.15	134.10
132.25	133.20	134.15
132.30	133.25	134.20
132.35	133.30	134.25
132.40	133.35	134.30
132.45	133.40	134.35
132.50	133.45	134.40
132.55	133.50	134.45
132.60	133.55	134.50
132.65	133.60	134.55
132.70	133.65	134.60
132.75	133.70	134.65
132.80	133.75	134.70
132.85	133.80	134.75
132.90	133.85	134.80

Group C *(cont.)*

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
134.85	135.25	135.65
134.90	135.30	135.70
134.95	135.35	135.75
135.00	135.40	135.80
135.05	135.45	135.85
135.10	135.50	135.90
135.15	135.55	135.95
135.20	135.60	

GROUP D

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
132.025	134.025	136.000
132.075	134.075	136.025
132.125	134.125	136.050
132.175	134.175	136.075
132.225	134.225	136.100
132.275	134.275	136.125
132.325	134.325	136.150
132.375	134.375	136.175
132.425	134.425	136.200
132.475	134.475	136.225
132.525	134.525	136.250
132.575	134.575	136.275
132.625	134.625	136.300
132.675	134.675	136.325
132.725	134.725	136.350
132.775	134.775	136.375
132.825	134.825	136.400
132.875	134.875	136.425
132.925	134.925	136.450
132.975	134.975	136.475
133.025	135.025	136.500
133.075	135.075	136.525
133.125	135.125	136.550
133.175	135.175	136.575
133.225	135.225	136.600
133.275	135.275	136.625
133.325	135.325	136.650
133.375	135.375	136.675
133.425	135.425	136.700
133.475	135.475	136.725
133.525	135.525	136.750
133.575	135.575	136.775
133.625	135.625	136.800
133.675	135.675	136.825
133.725	135.725	136.850
133.775	135.775	136.875
133.825	135.825	136.900
133.875	135.875	136.925
133.925	135.925	136.950
133.975	135.975	136.975

Note.—Frequencies between 136 and 136.975 MHz are not available for international use before 1990.

GROUP E

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
118.025	119.225	120.425
118.075	119.275	120.475
118.125	119.325	120.525
118.175	119.375	120.575
118.225	119.425	120.625
118.275	119.475	120.675
118.325	119.525	120.725
118.375	119.575	120.775
118.425	119.625	120.825
118.475	119.675	120.875
118.525	119.725	120.925
118.575	119.775	120.975
118.625	119.825	121.025
118.675	119.875	121.075
118.725	119.925	121.125
118.775	119.975	121.175
118.825	120.025	121.225
118.875	120.075	121.275
118.925	120.125	121.325
118.975	120.175	121.375
119.025	120.225	123.725
119.075	120.275	123.775
119.125	120.325	123.825
119.175	120.375	123.875

Group E *(cont.)*

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
123.925	125.075	126.225
123.975	125.125	126.275
124.025	125.175	126.325
124.075	125.225	126.375
124.125	125.275	126.425
124.175	125.325	126.475
124.225	125.375	126.525
124.275	125.425	126.575
124.325	125.475	126.625
124.375	125.525	126.675
124.425	125.575	126.725
124.475	125.625	126.775
124.525	125.675	126.825
124.575	125.725	126.875
124.625	125.775	126.925
124.675	125.825	126.975
124.725	125.875	127.025
124.775	125.925	127.075
124.825	125.975	127.125
124.875	126.025	127.175
124.925	126.075	127.225
124.975	126.125	127.275
125.025	126.175	127.325

Group E *(cont.)*

Frequency (MHz)	*Frequency (MHz)*	*Frequency (MHz)*
127.375	128.525	129.675
127.425	128.575	130.925
127.475	128.625	130.975
127.525	128.675	131.025
127.575	128.725	131.075
127.625	128.775	131.125
127.675	128.825	131.175
127.725	128.875	131.225
127.775	128.925	131.275
127.825	128.975	131.325
127.875	129.025	131.375
127.925	129.075	131.425
127.975	129.125	131.475
128.025	129.175	131.525
128.075	129.225	131.575
128.125	129.275	131.625
128.175	129.325	131.675
128.225	129.375	131.725
128.275	129.425	131.775
128.325	129.475	131.825
128.375	129.525	131.875
128.425	129.575	131.925
128.475	129.625	131.975

Note.— Guidance material relating to the distance separation required to prevent harmful interference between ILS and VOR when using the band 108-111.975 MHz is to be found in Section 3 of Attachment C to Part I.

4.2.2 For regional assignment planning, the frequencies for ILS facilities shall be selected in the following order:

a) localizer channels ending in *odd tenths* of a megahertz and their associated glide path channels;

b) localizer channels ending in *odd tenths plus a twentieth* of a megahertz and their associated glide path channels.

4.2.2.1 ILS channels identified by localizer frequencies ending in an *odd tenth plus one twentieth* of a megahertz in the band 108-111.975 MHz shall be permitted to be utilized on the basis of regional agreement when they become applicable in accordance with the following:

a) for restricted use commencing 1 January 1973;

b) for general use on or after 1 January 1976.

Note.— See Note to 4.2.3.1 below.

4.2.3 For regional assignment planning, the frequencies for VOR facilities shall be selected in the following order:

a) frequencies ending in *odd tenths* of a megahertz in the band 111.975-117.975 MHz;

b) frequencies ending in *even tenths* of a megahertz in the band 111.975-117.975 MHz;

c) frequencies ending in *even tenths* of a megahertz in the band 108-111.975 MHz;

d) frequencies ending in *50 kHz* in the band 111.975-117.975 MHz, except as provided in 4.2.3.1 below;

e) frequencies ending in *even tenths plus a twentieth* of a megahertz in the band 108-111.975 MHz except as provided in 4.2.3.1 below.

4.2.3.1 Frequencies for VOR facilities ending in *even tenths plus a twentieth* of a megahertz in the band 108-111.975 MHz and all frequencies ending in *50 kHz* in the band 111.975-117.975 MHz shall be permitted to be utilized on the basis of a regional agreement when they have become applicable in accordance with the following:

a) in the band 111.975-117.975 MHz for restricted use;

b) for general use in the band 111.975-117.975 MHz at a date fixed by the Council but at least one year after the approval of the regional agreement concerned;

c) for general use in the band 108-111.975 MHz at a date fixed by the Council but giving a period of two years or more after the approval of the regional agreement concerned.

Note.— "Restricted use", where mentioned in 4.2.2.1 a) and 4.2.3.1 a) above, is intended to refer to the limited use of the frequencies by only suitably equipped aircraft and in such a manner that:

a) the performance of ILS or VOR equipment not capable of operating on these frequencies will be protected from harmful interference;

b) a general requirement for the carriage of ILS or VOR airborne equipment capable of operation on these frequencies will not be imposed; and

c) operational service provided to international operators using 100 kHz airborne equipment is not derogated.

4.2.4 To protect the operation of airborne equipment during the initial stages of deploying VORs utilizing 50 kHz channel spacing in an area where the existing facilities may not fully conform with the Standards in Part I, Chapter 3, all existing VORs within interference range of a facility utilizing 50 kHz channel spacing shall be modified to comply with the provisions of Part I, 3.3.5.7.

4.2.5 *Frequency deployment.* The geographical separation between facilities operating on the same and adjacent frequencies shall be determined regionally and shall be based on the following criteria:

a) the required functional service radio of the facilities;

b) the maximum flight altitude of the aircraft using the facilities;

c) the desirability of keeping the minimum IFR altitude as low as the terrain will permit.

Note.— Guidance material on this subject is contained in the Attachments to this Annex.

4.2.6 **Recommendation.—** *To alleviate frequency congestion problems at locations where two separate ILS facilities serve opposite ends of the same runway or different runways at the same airport, the assignment of identical ILS localizer and glide path paired frequencies should be permitted provided that:*

a) the operational circumstances permit;

b) each localizer is assigned a different identification signal;

c) arrangements are made whereby the localizer and glide path not in operational use cannot radiate.

Note.— The Standards in Part I, 3.1.2.7.2 and 3.1.3.9, specify the equipment arrangements to be made.

4.3 Utilization in the band 960-1 215 MHz for DME

Note.— Guidance on the frequency planning of channels for DME systems is given in Attachment C to Part I, 7.3.8.

4.3.1 DME operating channels bearing the suffix "X" or "Y" in Table A of Part I, Chapter 3 shall be chosen on a general basis without restriction.

Note.— The channel pairing plan provides for the use of certain Y channels with either VOR or MLS. The guidance material at 7.3.8 includes specific provisions relating to situations where the same, or adjacent channel, is used in the same area for both systems.

4.3.2 DME channels bearing the suffix "W" or "Z" in Table A of Part I, Chapter 3 shall be chosen, on the basis of regional agreement when they become applicable in accordance with the following:

a) for restricted regional use on or after, whichever is the later, of:

1) 1 January 1989; or

2) a date prescribed by the Council giving a period of two years or more following approval of the regional agreement concerned;

b) for general use on or after, whichever is the later, of:

1) 1 January 1995; or

2) a date prescribed by the Council giving a period of two years or more following approval of the regional agreement concerned.

Note.— "Restricted use" is intended to refer to the limited use of the channel by only suitably equipped aircraft and in such a manner that:

a) the performance of existing DME equipment not capable of operating on these multiplexed channels will be protected from harmful interference;

b) a general requirement for the carriage of DME airborne equipment capable of operating on these multiplexed channels will not be imposed; and

c) operational service provided to international operators using existing DME equipment without the multiplexed channel capability is not derogated.

4.3.3 For regional assignment planning, the channels for DME associated with MLS shall be selected from Table 4-2.

4.3.3.1 *Groups 1-5.* These DME channels shall be permitted to be used generally. In selecting channels for assignment purposes the following rules are applicable:

a) when an MLS/DME is intended to operate on a runway in association with an ILS, the DME channel, if possible, shall be selected from Group 1 or 2 and paired with the ILS frequency as indicated in the DME channelling and pairing table in Table A of Part I, Chapter 3. In cases where the composite frequency protection cannot be satisfied for all three components, the MLS channel may be selected from Group 3, 4 or 5;

Table 4-2

Group	*DME channels*	*Associated paired VHF channels*	*Remarks*	*Assignment procedure*
1	EVEN 18X to 56 X	ILS 100 kHz spacings	Would normally be used if a single DME is paired with ILS and is part of MLS	for general use (see 4.3.1)
2	EVEN 18Y to 56Y	ILS 50 kHz spacings		
3	EVEN 80Y to 118Y	VOR 50 kHz spacings Odd tenths of a MHz		
4	ODD 17Y to 55Y	VOR 50 kHz spacings		
5	ODD 81Y to 119Y	VOR 50 kHz spacings Even tenths of a MHz		
6	EVEN 18W to 56W	No associated paired VHF channel		for later use (see 4.3.2)
7	EVEN 18Z to 56Z	No associated paired VHF channel		
8	EVEN 80Z to 118Z	No associated paired VHF channel		
9	ODD 17Z to 55Z	No associated paired VHF channel		
10	ODD 81Z to 119Z	No associated paired VHF channel		

Note.— DME channels in Groups 1 and 2 may be used in association with ILS and/or MLS. DME channels in Groups 3, 4 and 5 may be used in association with VOR or MLS.

b) when an MLS/DME is intended to operate on a runway without the coexistence of an ILS, the DME channel to be used shall preferably be selected from Group 3, 4 or 5.

4.3.3.2 *Groups 6-10.* These DME channels shall be permitted to be used on the basis of a regional agreement when they have become applicable in accordance with the conditions specified at 4.3.2 above.

4.3.4 **Recommendation.—** *Co-ordination of regional DME channel assignments should be effected through ICAO.*

4.4 Utilization of the frequency band 5 031-5 091 MHz

Note.— Guidance material on the frequency protection planning of MLS facilities is contained in Attachment G to Part I, 9.

4.4.1 The MLS channels shall be selected from the 200 channels as specified at Table A of Part I, Chapter 3.

4.4.2 For regional planning purposes MLS channels shall be selected in accordance with the conditions specified in 4.3.3 above for the associated DME facility.

ATTACHMENTS TO ANNEX 10 — VOLUME I

ATTACHMENT A TO PART I. — RECOMMENDATIONS OF COUNCIL CONCERNING THE UTILIZATION OF FACILITIES, RESEARCH, DEVELOPMENT AND EVALUATION

The Council, at the Sixth meeting of its Seventh Session (30 May 1949), after having adopted Annex 10, resolves that the following special Recommendations be communicated to Contracting States.

1. Utilization of facilities not covered by Annex 10

1.1 Short-distance radio aids to navigation and aids to final approach and landing

The Council recommends that:

a) systems and equipment for short-distance radio aids to navigation or radio aids to final approach and landing, not specified in Annex 10, be retained, or extended as necessary, to meet the immediate requirements of international civil aviation, pending the availability of preferred systems, or when installation of the standard aid is not practicable;

b) non-visual aids to approach and landing that can be used in whole or in part by aircraft and equipment designed for use with the ILS, but which inherently are not capable of meeting in all respects the Standards contained in Part I, Chapter 3, of Annex 10, should be adjusted to approximate as nearly as practicable to these Standards;

c) after the installation of aids at particular locations, in compliance with Annex 10, existing types of aids be retained or installed at such locations and be maintained in use so long as their service to international civil aviation can be justified economically.

1.2 Other aids

The Council recommends that systems and equipment at present in existence to meet requirements other than those for short-distance and long-distance radio aids to navigation and aids to final approach and landing be retained, or extended as necessary, to meet the requirements of international civil aviation pending the development of Standards and Recommended Practices for such aids.

2. Research, development and evaluation of radio aids to air navigation

2.1 General

2.1.1 The Council considers that continued development and operational improvement of the aids to navigation prescribed in the Annex to the Convention are essential to the stability of such Standards. Furthermore, research and development and operational evaluation of further aids to navigation, which may at some time in the future culminate in Standards and Recommended Practices, are essential to progress in aviation.

2.1.2 The Council recommends that the attainment of complete satisfaction of the functional requirements as approved from time to time by the Council be the objective guiding all research and development.

2.2 Aids to final approach and landing

2.2.1 The Council considers that, in the field of non-visual aids to final approach and landing, a promising line of development lies in the field of microwave techniques, and recommends that investigation along this line, and along other promising lines of development in this field, be pursued actively with the aim of producing a complete landing system that will satisfy the functional requirements. The development of ground search primary radar should be continued to produce equipment that will meet the functional requirements of such aids, although standardization may not be necessary.

The following Recommendation was initially made by the Council at the Seventh meeting of its Twenty-eighth Session, 11 May 1956, and was revised by the Council at the Twelfth meeting of its Fifty-ninth Session, 12 December 1966:

2.2.2 The Council recommends that, in respect of the siting of the inner and middle marker beacons contained in Part I, Chapter 3 of Annex 10, Contracting States give attention to the views expressed in the reports of the Second and Fourth Air Navigation Conferences as follows:

2.2.2.1 From the Second Air Navigation Conference:

Experience of operation of ILS has shown that the inner marker does not provide the pilot with any information

essential to a successful approach (it is not intended to imply that the information it provides is of no service to the pilot in some circumstances).

2.2.2.2 From the Fourth Air Navigation Conference:

Inner and middle markers sited at any particular site may not fully satisfy the operational requirements. In this case, the ideal solution may lie in the availability of continuous information regarding distance from the threshold. The means for providing such an ideal solution to the problem are under study in some States. One State was already making use of this means for Category I operations.

2.3 Short-distance aids to air navigation

The Council recommends that:

a) in the field of short-distance radio aids to air navigation, the development and operational improvement of the CW omni-range and DME be continued with the objective of satisfying completely the functional requirements;

b) if a Contracting State determines that there is a probability that such aids as the VHF multi-track pulse range, the GEE system or other aids can satisfy more fully the functional requirements that the CW omni-range and DME, their development and operational evaluation be continued or undertaken;

c) serious consideration be given to development which will make possible the integration of the short-distance aids and aids to final approach and landing.

2.4 Long-distance aids to air navigation

2.4.1 The Council considers that the following material, developed by the Fourth Air Navigation Conference, should be used as a basis for operational and technical planning and as guidance for related research and development activity in the field of long-distance navigation:

Operational requirements for long-distance navigating capability

1. *Foreword*

1.1 The rapid technological development of self-contained* aids has resulted in significant changes in the possible means of satisfying the requirements for long-distance navigation. There is a growing realization that, for certain operations, navigation may be conducted solely by self-contained aids. On the other hand, station-referenced* aids may continue to play a role, either as a prime navaid or as part of the complete navigation system. The significance of the above is that a complete long-distance navigation system must now be considered to be either a self-contained or a station-referenced aid, or a combination of both. Although certain aircraft may be equipped to use only one of the two types, others will be equipped to use both. The term "system", as used in these operational requirements, is intended to describe the total navigational capability of an aircraft, however derived. The complexity of the system required will be determined by the environment in which it is to be used.

**Note.— "Station-referenced" aids are understood to include "ground-referenced" or "satellite-referenced" aids.*

"Self-contained" aids are understood to include "Doppler radar", "inertial navigation", and "celestial navigation" or combinations thereof.

1.2 The statement of operational requirements recognizes that:

1.2.1 A basic requirement of any national or world-wide system is that it must be suitable for use in all the aircraft types which may require the service.

1.2.2 There are two requirements for navigational capability: one, that of conducting a flight from one place to another safely and economically, and the other, which arises from the needs of ATS, including those associated with SAR, in certain areas. The relative severity of these two requirements will vary with place and time.

1.2.3 The required level of performance of the navigation system for long-distance operation is not constant throughout the world since the required position and tracking accuracy of the system is a function of the density of traffic in each particular ATS environment, which itself is subject to change with time.

1.2.4 No one set of operational requirements, even though it meets the basic requirement of safety, can adequately reflect the many different combinations of operating conditions encountered in various parts of the world, in that the requirements applicable to the most exacting region may be rather extravagant when applied to others.

1.2.5 The system should be capable of integration with the flight control system of the aircraft to provide automatic tracking.

1.2.6 Requirements for flight deck presentation of navigation information should be considered, as well as the more usual features such as position fixing, accuracy, reliability, etc.

1.2.7 The long-distance system should be used primarily along routes where short-distance station-referenced aids do not provide the desired service, although it may also be applicable in certain short-distance environments.

1.3 The following conclusions were reached in developing the operational requirements:

1.3.1 That in the operational requirements as presented, there is no requirement for a world standard station-referenced aid, either for use alone or with self-contained capability at this time.

1.3.2 In the future a need may arise for a world standard station-referenced aid but this is by no means certain. Research and development should, however, continue to carry out feasibility studies to ascertain the possible future need for such an aid and the means of fulfilment.

1.3.3 There appears no need for international standardization of self-contained aids, provided that they meet agreed requirements for accuracy and reliability for aircraft navigation and air traffic separation.

1.3.4 To support separation standards even smaller than those now envisaged for the most critical area, research and development should be encouraged to carry out feasibility studies. An accuracy figure of 9.3 km (5 NM) standard deviation has been suggested as a goal.

1.3.5 The most critical accuracy requirement is considered to be associated with the North Atlantic where need for a lateral separation standard of 111 km (60 NM) has been envisaged, based on current traffic forecasts. In other cases, the most critical requirement arises when the long-distance system is used in transition to critical continental routes. For non-critical areas, the accuracy should not be less than that necessary to permit safe, smooth integration with a short-distance navigation aid.

1.3.6 In assessing collision risk, it is unrealistic to assume that all of the protection should necessarily be provided in one of the dimensions alone. Achievement of safe separation is a three-dimensional consideration. Separation standards in each of the three dimensions provide the required protection, and this fact should be considered in assessing navigation accuracy requirements in the development of separation standards.

1.3.7 Separation standards provide full protection against normal errors in the navigation system but not against all gross errors. Maximum protection against blunders which can often cause gross errors can be achieved by attacking their causes and reducing their occurrence. This can be facilitated by the development and application of appropriate procedures, and by providing cockpit presentation of navigation information that has the continuity and consistency to make blunders unlikely, or at least to ensure early blunder detection.

2. *Statement of operational requirements*

2.1 *Coverage.* The system should be capable of providing service over all the used airspace of the world, regardless of time, weather, altitude, terrain and propagation characteristics.

2.2 *Reliability/Integrity.* The over-all integrity of the system, including the presentation of information in the cockpit, shall be as near 100 per cent as is achievable and, to the extent feasible, should provide flight deck warnings in the event of failure, malfunction or interruption.

Note.— It is recognized that, in the various arrangements which may be employed to meet the total requirement, many different ways of approaching the reliability requirement could be utilized, including the use of such concepts as equipment duplication, monitoring and system combinations.

2.3 *Ambiguity.* The navigational information provided by the system must be free from unresolved ambiguities of operational significance.

2.4 *Capacity.* Any station-referenced component of the total navigational system shall be capable of providing navigational information simultaneously to all aircraft which require access to it.

2.5 *Presentation.* The system must have the capability of providing the pilot with a continuously available indication of present position in an operationally meaningful manner, and with information enabling him to follow the designated track with the accuracy required and to estimate further progress of the flight.

2.6 *Compatibility.* The long-distance navigation system must, from an operational viewpoint, permit smooth integration with navigation requirements applicable in other phases of flight.

2.7 *Accuracy.* The system must provide the navigational capability needed in specific areas and permit the application of the horizontal separation minima necessary so as to accommodate present and forecast traffic over the next decade.

Note 1.— The accuracy most likely to be required in the most critical specific area (North Atlantic) is approximately 18.5 km (10 NM) standard deviation in order to support a 111 km (60 NM) lateral separation standard.

Note 2.— The above values take into account the need to reduce blunders. In the opinion of some States, when considering this aspect, for at least 99.95 per cent of the time, the aircraft should not be farther from the assigned track than a distance equivalent to half the lateral separation standard in use.

2.5 Other aids

The Council considers that extensive development and evaluation are needed in the fields of aids for use in the movement area, aids to traffic control and in aids to collision prevention.

2.6 Exchange of information

2.6.1 The Council considers that the prompt and efficient utilization of improved techniques would be aided by an exchange of current information on new air navigation systems and on the results of researches relating thereto.

2.6.2 The Council recommends that such information should be communicated to the Secretariat of ICAO, for dissemination to Contracting States and interested groups within those States.

ATTACHMENT B TO PART I. — GUIDANCE MATERIAL RELATED TO THE SECONDARY SURVEILLANCE RADAR (SSR) SYSTEM CHARACTERISTICS

1. Facilities

The main facilities offered by SSR are:

1.1 Aircraft positional information without necessarily making use of decoding facilities.

1.2 Initial and continuous identification on the display of signals from groups of aircraft, either associated with a particular function or operating in a particular part of the airspace. This can be accomplished by the use of encoding and decoding facilities.

1.3 Identification on the display, when requested, of an individual aircraft signal within the categories outlined in 1.1 or 1.2 above, by the use of the transponder special position identification facility.

1.4 Immediate indication of aircraft transmitting emergency signals or experiencing a radiocommunication failure, when suitable ground facilities are provided.

1.5 Automatic pressure-altitude transmission.

2. Performance objectives

2.1 A consideration of present and anticipated aeronautical operational practices indicates that the SSR system should, in order to give a clear, unambiguous display compatible with the display of any associated primary radar, be designed to:

2.1.1 Provide signals to augment desired radar returns. This requires standardization of the ground-to-air and air-to-ground channel characteristics of the SSR system.

2.1.2 Provide means of aircraft identification through the transmission of pulse coded replies from the aircraft.

Note.— Methods which may be used on the ground to utilize pulse coded replies from an aircraft include:

— The unaltered display of airborne transponder replies, either alone or when correlated on the plan position indicator (PPI) with primary radar returns.

— The segregation of airborne transponder replies by electronic decoding and their display in any desired combination on the same or separate PPIs.

— The segregation of airborne transponder replies by codes and their use to actuate pictorial or symbolic displays of information. (A number of decoding and display systems have been developed for use in correlating the SSR system replies to the primary radar display. The type of decoding system, if any, and display system to be employed in a specific application should be selected by the implementing Administration on the basis of the particular operational situation.)

— The use of some codes to relay specific predetermined messages of extreme importance offers particular advantages in special circumstances. [The ground decoding equipment may be designed to provide aural and visual alarm signals upon the receipt of Code 7700 (emergency) and/or Code 7600 (loss of radiocommunications). Such arrangements are normally associated with special RAC procedures.]

2.1.3 Display airborne transponder replies only at bearings and distances corresponding to actual positions. All equipped aircraft within the volume of coverage must be "seen" in a manner which permits continuity of tracking to within 1.85 km (1 NM) of the interrogator.

2.1.4 Provide an over-all resolution comparable to that of the primary radar with which it may be associated.

2.1.5 Provide service under all weather conditions at all bearings and at all distances between 1.85 and 370 km (1 and 200 NM), and at all operational altitudes up to at least 30 480 m (100 000 ft) above mean sea level between at least the angles of elevation of 0.5 degree and 45 degrees. When appropriate for a specific service application in which the system is to be employed, service to less than or more than the distance and altitude specified above may be provided.

2.1.6 Give an acceptable grade of service (90 per cent replies) in areas where a number of ground interrogators may interrogate an aircraft.

2.1.7 Perform its operational function without degrading the performance of other radio or radar equipment.

2.1.8 Perform its functions during all normal manoeuvres of the aircraft.

3. Factors affecting optimum utilization of the system

3.1 A number of specific precautions may be taken in order to obtain maximum utilization of the SSR system, such as:

3.1.1 Co-ordination of the number and type of interrogators installed in a particular location, and co-operative

use of interrogators, where possible for several related functions.

3.1.2 Use for each interrogator of the lowest interrogation rate which is required to perform its function.

3.1.3 Use for each interrogator of the lowest power output which is required for it to provide satisfactory performance.

3.1.4 Use of particular interrogators only during the periods necessary for them to perform their function.

3.1.5 Limitation of antenna beam width to the minimum required and use of low side-lobe antennas.

3.1.6 Use of defruiting equipment on the ground to minimize the number of non-synchronized replies displayed.

3.1.7 Co-ordination of the interrogation repetition frequency used to minimize interference.

4. Considerations on the application of the SSR system

4.1 Siting

Care should be taken in siting the ground interrogator to ensure that the number of ground installations is kept to a minimum consistent with the operational requirement for SSR information. It should be emphasized that the effects obtained by reflection of the main lobe are more serious than those associated with primary radar. It is therefore necessary to ensure that no large vertical reflecting surfaces are within a reasonable distance of the SSR interrogator antenna. This distance will depend on the area of the reflecting surface and its elevation with respect to the interrogator but, as a guide, it is desirable to site the interrogator at least 0.93 km (0.5 mi) away from large metal structures. Although it may be desirable to associate the interrogator antenna physically with a primary radar antenna, siting and maintenance considerations may make it necessary to have a separate site for the interrogator. When this is necessary, the rotation of the two antennas should be synchronized with a maximum error of 1 degree.

4.2 Interrogator antenna

It is necessary that the side-lobe level of the antenna relative to the main lobe be as low as practicable. A level lower than minus 24 dB is desirable. It is important that the interrogation beam width be kept as narrow as possible, normally of the order of 3 degrees, but it should be noted that there is a minimum number of replies necessary for processing and display. This minimum will depend on the particular processing and display facilities provided, but would, typically, fall in the range of 4 to 8 replies per beam width on each interrogation mode.

4.2.1 Side-lobe suppression requires two radiation patterns: a directional pattern to radiate the interrogation pulses, and an omnidirectional pattern to radiate the control pulse. It should be noted that "omnidirectional", as used here, assumes that adequate power is radiated in all directions, not necessarily that equal power is radiated in all directions. It is necessary that the control pattern be in the right relationship to the interrogation pattern over the operational angles of elevation. This may demand that the antennas be designed in a common assembly so that the same effective height above the ground can be maintained for both.

4.2.2 Some antenna sites may experience severe reflection problems and re-siting may not be practicable. Satisfactory performance is possible in most cases by exploiting the characteristic of transponders that requires them not to reply for 35 plus or minus 10 microseconds after suppression by a pair of pulses conforming to Part I, 3.8.7.4.1. Since transponders will not reply to interrogations falling within a suppression period, it is necessary to provide for additional suppression in areas where reflections occur. One technique makes use of an omnidirectional antenna to radiate P_1 in addition to P_2. Suppression is then assisted throughout the side-lobe region. Another technique makes use of an additional directional antenna to radiate synchronized suppression pairs into the reflection area when the main interrogator beam is sweeping the reflecting surface. This assists suppression over a sector determined by the directivity of the additional antenna. In applying these techniques, the power radiated from this additional antenna should be kept to the minimum required to overcome the particular reflection problem and within the narrowest possible sector.

4.3 Interrogator power

The coverage stated in the performance objective 2.1.5 above can be met by an interrogator having the following output power characteristics:

4.3.1 Directional radiation between 500 W and 1.5 kW power (peak pulse) dependent upon the gain of the antenna system used.

4.3.2 Omnidirectional radiation approximately 500 W to 9 kW power (peak pulse) dependent on the effective beam width and gain of the omnidirectional antenna.

4.3.3 Where the full coverage of the system is not required, the interrogator power should be reduced as noted in Part I, 3.8.8.2.

4.4 Interrogator receiver bandwidth

The bandwidth of the receiver should be adequate to reproduce faithfully the pulses transmitted by the transponder (pulse rise time 0.1 microsecond), to accommodate the drift in transponder transmitter frequency (plus or minus 3 MHz) and to accommodate its own local oscillator drift. Outside the necessary pass band of the receiver, it is desirable that sufficient rejection be available to eliminate high power primary radar pulses from the video output.

The video response should be capable of reproducing the pulse trains specified in the Standard, without appreciable pulse stretching or distortion over the dynamic range required.

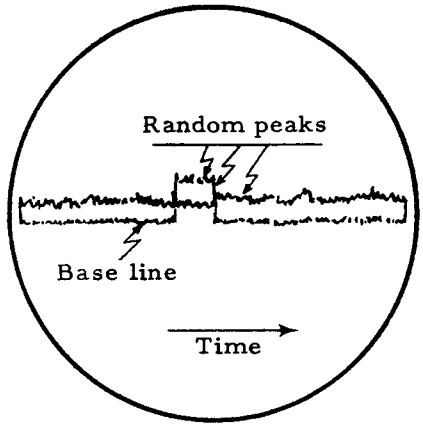


Figure B-1. Pulse signal on an A-scope with square-law second detector

4.5 Interrogator receiver sensitivity

For a 370 km (200 NM) facility, the receiver sensitivity should not be less than 85 dB below 1 mW when measured by the method illustrated in Figure B-1. This method uses, as the criterion, a pulse signal that raises the observed noise amplitude by its own height as shown. To minimize unnecessary signals at short range, it is desirable to have a method of reducing the receiver sensitivity to a pre-set level at the time of transmission of the interrogator pulses, and to increase the sensitivity to a normal level at a pre-set rate.

At 15.36 microseconds (corresponding to 1.85 km (1 NM) plus transponder delay) after pulse P_3, the gain should normally be reduced to a value between 10 dB and 50 dB below maximum sensitivity. The recovery rate should be adjusted to suit local conditions. A rate of 6 dB for each doubling of range is satisfactory for most applications.

4.6 Rejection of unwanted responses

In an area where a large number of ground interrogators are necessary, there will be a considerable number of transponder responses, which have been triggered by other interrogators, received at any one ground equipment. The responses will be received at recurrence frequencies which will, in all probability, be different from that of the interrogator receiving the information and will constitute a nuisance called "fruit" (unsynchronized replies) on the radar display. Defruiting techniques which use delay lines, storage tubes, or digital storage to defruit on a pulse-to-pulse basis should be employed to remove these non-synchronous replies. The defruiting function may also be an integral part of the digital detection process.

4.7 Monitoring of SSR interrogator

4.7.1 The performance monitoring of the ground interrogator called for in Part I, 3.8.10 is required to provide responsible personnel with an indication that the equipment is functioning satisfactorily within the system limits prescribed in Part I, and to give an immediate indication of any significant fault developing in the equipment. To this end, it is desirable that continuous monitoring provisions with respect to at least the system parameters listed hereafter in 4.7.1.1 and 4.7.1.2 be provided and that, additionally, an alarm indication be given in the event of a failure of the monitor itself.

4.7.1.1 *Pulse intervals (Part I, 3.8.4.3 and 3.8.4.4).* Means should be provided to measure pulse spacing for all modes which are to be employed.

4.7.1.2 *Interrogator relative radiated pulse levels (Part I, 3.8.5.1).* When side-lobe suppression is provided, monitoring of this parameter is most important and should be associated with the tolerances indicated in 3.8.5.1.

4.7.2 Monitoring of the following SSR system parameters is also desirable; however, checking on a periodic basis should suffice.

4.7.2.1 *Interrogator radio frequencies (Part I, 3.8.1).* Assuming that a high stability crystal controlled oscillator is used as the frequency control element of the SSR, it will be necessary only on a periodic basis to determine that the tolerances specified in 3.8.1.2 and 3.8.1.3 are satisfied.

4.7.2.2 *Interrogator pulse duration (Part I, 3.8.4.5).*

4.7.2.3 *Receiver sensitivity (4.5 of this Attachment).*

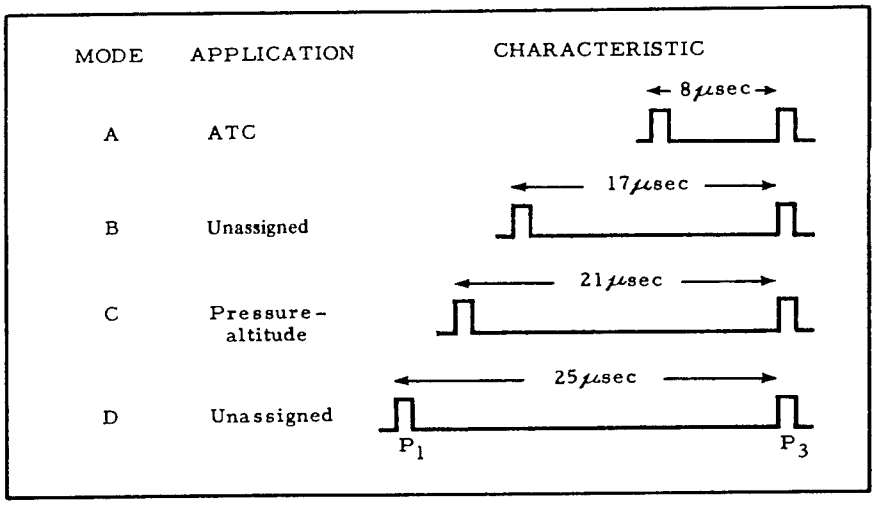


Figure B-2. SSR interrogation modes

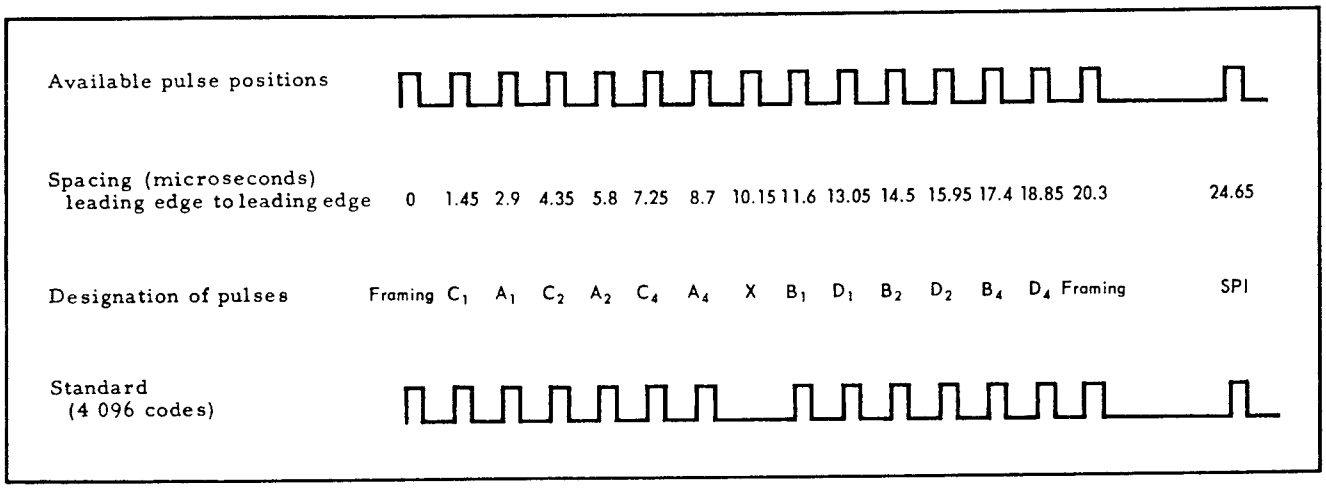


Figure B-3. SSR transponder reply codes

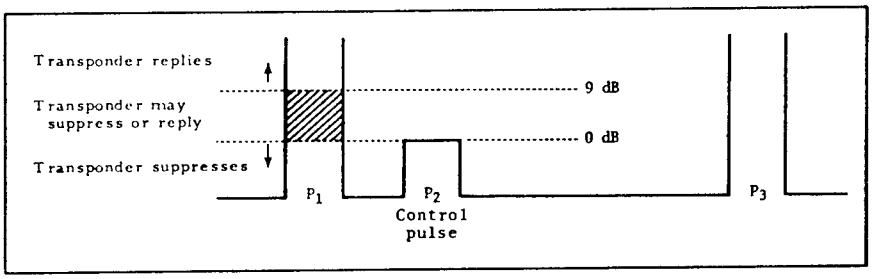


Figure B-4. Pulse amplitude discrimination in transponder for side-lobe suppression facility

4.7.2.4 *Radiated power (Part I, 3.8.8.2).*

4.7.2.5 *Spurious radiation (Part I, 3.8.11.1).*

4.7.3 The precise location of the monitor warning indication is a matter for determination by the Administration concerned in the light of local circumstances, but should take into account the need to prevent the presentation of erroneous information to the controller without his knowledge.

4.8 Airborne equipment

4.8.1 *Transponder peak power output and sensitivity.* System requirements can be met by a transponder having a nominal output of 500 W (peak pulse) and a nominal minimum triggering level (MTL) of minus 74 dBm dependent upon the gain or loss of the antenna system used.

4.8.1.1 For the MTL and peak pulse power specified in Part I, 3.8.7.5.1 b) and 3.8.7.11.1, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter wave antenna are assumed. In the event these conditions do not apply, the MTL and peak pulse power of the installed transponder system should be comparable at least to that of the assumed system.

4.8.1.2 Specifications for SSR transponders and interrogation facilities in Part I outline functional requirements for Modes A and C. In SSR system design, States and aircraft operating agencies should recognize the possible need for future expansion of the system to include the use of either or both Modes B and D. No functional need for Mode B or Mode D has been defined. However, if it is desired to make technical provisions for possible future implementation of Modes B and D, decoding of Modes B and D interrogation pulses specified in Part I would be required, and such future use might involve automatic response without pilot intervention. Should the system be expanded to make functional use of Mode B or Mode D to satisfy operational requirements that may be agreed by ICAO, the functional use of Mode D should be a first consideration in order to safeguard the possible national interests of States which may require Mode B for domestic purposes until such time as international agreement on the use of Mode B is reached.

4.8.2 *Antenna.* A technique which uses two transponders connected to separate antennas must be considered with extreme caution. Such an arrangement, unless carefully controlled, could result in unsatisfactory performance because of the difficulty of matching transponder parameters. This technique requires matching of the relevant characteristics specified in Part I, 3.8 and, in particular, matching of the reply delay (Part I, 3.8.7.10) to within 0.2 microsecond. Any switching device that alternately changes the transponder from one antenna to another at a pre-set rate should be avoided. A preferred method, if dual antennas are used, is through received signal amplitude comparison whereby the transponder reply is routed to the antenna which receives the stronger interrogation signal.

4.8.3 *Transponder tester.* A transponder in-flight tester may be provided to indicate normal or faulty operation.

4.8.3.1 When a tester is used it should not radiate a signal level external to the aircraft stronger than minus 70 dBm. The test interrogation signal should not exceed an interrogation rate of 450 per second.

4.8.3.2 The transponder tester should be limited to intermittent use which is no longer than that required to determine the status of the transponder.

4.8.4 *Pressure-altitude transmission.* In order to achieve maximum operational benefit from automatic pressure-altitude transmission, the altitude information used by the pilot and that automatically provided to the controller must closely correspond (see Part I, 3.8.7.12.2.5). The highest degree of correspondence will be achieved by having airborne systems which use the same static pressure source, same aneroid unit, same static pressure error correction device and same scale correction device for both the pilot and the automatically transmitted pressure-altitude data.

For aircraft installations which are not yet equipped with altitude digitizer units, the use of Mode C reply framing pulses only (see Part I, 3.8.7.12.2.2) is encouraged as an interim arrangement.

The wording of the Standard recognizes that facilities are provided on many transponders in service which only enable the information and framing pulses to be removed together. But its main objective is to ensure that inaccurate information pulses are removed while retaining the capability of position determination. The framing pulses alone are useful in certain ground processing equipments for enhancing the detection probability and azimuth accuracy.

The capability required by the Standard in Part I, 3.8.7.12.2.2 should be provided in new installations.

4.8.5 *Transmission of the "X" pulse.* In Part I, 3.8.6.2, the position of the "X" pulse is specified as a technical Standard to provide for possible future expansion of the system. It is recognized that, though a majority of airborne transponders of later design contain an "X" pulse position, there are no means at present embodied to permit the operational use of this pulse. To do so, modifications of existing transponders and/or ancillary equipment would be necessary. The extent of modifications required would depend on the future function of the "X" pulse.

5. SSR decoding and display facilities

5.1 There are three basic technical approaches to decoding and display of SSR data that have proved practical in application. These are:

a) passive decoding based on the utilization of 64 identity codes with collective presentation of aircraft and possible individual identification by use of SPI;

b) automatic decoding based on the utilization of 4 096 codes with numerical presentation on the radar display of individual identity codes and of altitude/flight level information derived from Mode C;

c) automatic decoding based on the utilization of 4 096 codes with alphanumeric presentation on the radar display of individual flight data by use of automatic correlation between individual codes and relevant flight plan data and including display of altitude flight level information derived from Mode C.

5.2 In the passive 64-code decoding system without Mode C reply decoding identified in 5.1 a) above, information can generally be selected in a number of ways, which include the following:

a) all codes can be decoded and displayed without any discrimination. Each signal is therefore only an indication of aircraft position;

b) only those replies employing a particular code or codes may be displayed when selected by the controller. The displayed signals can all be arranged to be of the same particular form so that an indication is given of the position of all aircraft replying with the selected code or codes;

c) a reply incorporating the special position identification pulse (in response to a radiotelephone request from the ground) can be displayed as a signal which can be distinguished from all other signals.

5.2.1 As an adjunct to the above, provision may be incorporated for active single-code decoding which allows the controller to select a particular SSR response on his radar display, using a strobe-indicating device, and the code from that SSR response would be displayed.

5.3 Both the approaches identified in 5.1 b) and c) above begin with automatic plot extraction. The difference between these approaches appears in the amount of processing and the display capabilities required. This is discussed in more detail in 5.4 and 5.5 below.

5.4 Provision for numeric display may require only that the controller be provided with the means, through input to the processor, of selectively filtering the data derived from the SSR plot extractor. Thereafter, the processor converts the selected SSR data to the appropriate numeric equivalents and routes them to the display.

5.4.1 Two general forms of controller input devices have proved effective.

5.4.1.1 The first provides a number of 4-digit code selectors which are used to select individual codes from the 4 096 identity codes available. A switch may be associated with each of these code selectors to immobilize the last two digit positions of a particular selector to enable all 64 individual codes of a basic code block to be passed to the display. Additional controls are provided to select display of Mode C altitude/flight level information. Usually one of these passes to the display the Mode C information correlated with selected identity code information. Another set of Mode C controls allows all Mode C information from aircraft within a selected altitude/flight level stratum to be passed.

5.4.1.2 The second form of input device uses a numeric and function keyboard to allow the controller to select those identity codes and that Mode C altitude/flight level information he desires to be displayed.

5.4.2 In either case provision is usually made for automatic alerting devices and display presentations for detection of emergency and radio failure SSR code responses.

5.4.3 Also, manual input of the current altimeter setting to the processor may be provided to enable automatic conversion of Mode C pressure-altitude data to altitude when such data indicates that the aircraft from which it is received is below the transition level.

5.5 Provisions may be added to the system described in 5.4 above for alphanumeric presentation on the radar display of individual flight data through automatic correlation between selected identity codes and relevant flight plan data. This requires full alphanumeric input devices, and more processing capability. For this reason, this approach to SSR decoding is often made a part of an over-all ATC automation system. [PANS-RAC (Doc 4444), Attachment D refers.]

5.5.1 Input of flight plan data is ordinarily performed at a central flight data section in the ATC unit or may be accomplished remotely from flight operations offices and by means of data interchange links with the ATC processors of adjacent ATC units. This minimizes the input workload imposed upon the controller. However, the controller requires an alphanumeric input device for incidental modification of displayed flight data.

5.6 Intermediate variations of the three basic approaches to SSR decoding and display may be implemented. For example, the passive 64-code system described in 5.2 above may be expanded to enable manual selection of individual 4-digit codes. Additionally, provision may be made for active decoding of Mode C altitude/flight level information from a particular aircraft in the manner described in 5.2.1 above.

5.7 In the choice of technical equipment for SSR decoding and display, account will need to be taken of the operational requirements of the ATC unit and of its workload characteristics. Recognition should be made of the growth in workload which may be anticipated, and the possible requirement in later years for increasing the capability of the equipment. In this regard, where a future need for the approach described in 5.5 above is envisaged, but cannot be justified for initial implementation, the approach described in 5.4 above may be found more suitable than the basic 64-code approach described in 5.2 above, with respect to possible subsequent progression to the more advanced capability of 5.5.

6. Automatic conversion of pressure-altitude data to altitude

6.1 Automatically transmitted pressure-altitude data obtained via SSR may be displayed to air traffic controllers directly after being decoded, when such data indicates that the

aircraft from which it is received is at or above the transition level. When the aircraft is below the transition level, such data could be misleading, since it is based upon the standard atmospheric pressure reference datum of 1 013.25 hPa while the pilot's altimeter is adjusted to a different reference. In this case, therefore, the data must be converted by application of an appropriate correction factor, based upon the same reference datum as that to which the pilot's altimeter is set.

ATTACHMENT C TO PART I. — INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE STANDARDS AND RECOMMENDED PRACTICES IN ANNEX 10

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 this Annex.

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 prefixes "nominal" and "indicated". Such usages are intended to convey the following meanings:

The prefix "nominal": *the design characteristics of an element or concept.*

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

Slant course line. The line formed at the intersection of the course surface and the plane of the nominal ILS glide path.

False ILS glide path. Those loci of points in the vertical plane containing the runway centre line at which the DDM is zero, other than that locus of points forming the ILS glide path.

Displacement error. The angular or linear displacement of any point of zero DDM with respect to the nominal course line or the nominal ILS glide path respectively.

Linearity sector. A sector containing the course line or ILS glide path, within a course sector or an ILS glide path sector, respectively, in which the increment of DDM per unit of displacement remains substantially constant.

Low DDM zone. A zone outside a course sector or an ILS glide path sector in which the DDM is less than the minimum value specified for the zone.

Note.— The minimum values of DDM related to such zones are specified in Part I, 3.1.3.7 and 3.1.5.6.

Plane of the nominal ILS glide path. A plane perpendicular to the vertical plane of the runway centre line extended and containing the nominal ILS glide path.

Definitions relating to the received radiation pattern

Indicated course line. The locus of points in any horizontal plane at which the receiver indicator deflection is zero.

Indicated ILS glide path. The locus of points in the vertical plane containing the runway centre line at which the receiver indicator deflection is zero.

Indicated slant course line. The line formed at the intersection of the indicated course surface and the plane of the nominal ILS glide path.

Indicated ILS glide path angle. The angle above the horizontal plane of the indicated ILS glide path.

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.

Indicated ILS glide path sector. The sector containing the indicated ILS glide path 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.

Incremental sensitivity. The increment of receiver indicator current per unit change of receiver antenna displacement from the nominal course line or nominal ILS glide path.

Flat zone. A zone within an indicated course sector or an indicated ILS glide path sector in which the slope of the sector characteristic curve is zero.

Reversal zone. A zone within an indicated course sector or an indicated ILS glide path sector in which the slope of the sector characteristic curve is negative.

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 Part I, 3.1.1 have operational objectives as follows:

Operational Performance Category I: Operation down to 60 m (200 ft) decision height and with a runway visual range not less than a value of the order of 800 m (2 600 ft) with a high probability of approach success.

Operational Performance Category II: Operation down to 30 m (100 ft) decision height and with a runway visual range not less than a value of the order of 400 m (1 200 ft) with a high probability of approach success.

Operational Performance Category IIIA: Operation, with no decision height limitation, to and along the surface of the runway with external visual reference during the final phase of the landing and with a runway visual range not less than a value of the order of 200 m (700 ft).

Operational Performance Category IIIB: Operation, with no decision height limitation, to and along the surface of the runway without reliance on external visual reference; and, subsequently, taxiing with external visual reference in a visibility corresponding to a runway visual range not less than a value of the order of 50 m (150 ft).

Operational Performance Category IIIC: Operation, with no decision height limitation, to and along the surface of the runway and taxiways without reliance on external visual reference.

Note 1.— The values given in feet are approximate rather than exact equivalents for those given in metres and they have been chosen on the basis of their operational significance in establishing runway visual range values.

Note 2.— The term "decision height" is defined in the ICAO PANS-OPS and the term "runway visual range" is defined in Annex 14.

2.1.2 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 above.

2.1.2.1 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 above.

2.1.2.2 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 Part I, 3.1.3.4.1 and extends down to the runway.

2.1.2.3 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 Part I, 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 above to be approved down to and below the values stated in the operational objectives described in 2.1 above.

2.1.2.5 An example of the classification system is presented in 2.14.3 below.

2.1.3 Guidance material relating to airborne equipment tolerances appropriate to the attainment of the objectives of ILS Operational Performance Categories I and II are given in 2.2.4 and 2.2.5 below. In the case of Category II operations utilizing appropriate ILS facilities, it may be feasible to allow operations by aircraft with low approach speeds and adequate demonstrable manoeuvrability fitted with airborne equipment having tolerances less stringent than those specified for Category II.

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 ILS glide path respectively, and 2.1.4 and 2.1.5 below have the same basis, the material in 2.1.6 below and Figure C-2 regarding the actual evaluation of bends in fact relates them to the mean positions of the course and path. This is because the aircraft recordings will ordinarily be in this form, and it is the short-term rather than the long-term excursions which are frequently more significant operationally. It should be noted that this material is tentative and is still under review.

2.1.4 *Course bends.* Localizer course bends should be evaluated in terms of the course structure specified in Part I, 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 Part I, 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.

2.1.5 *ILS glide path bends.* Bends should be evaluated in terms of the ILS glide path structure specified in Part I, 3.1.4.4. 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 Part I, 3.1.4.4, 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.

2.1.6 *Application of localizer course/glide path bend amplitude Standard.* In applying the specification for localizer

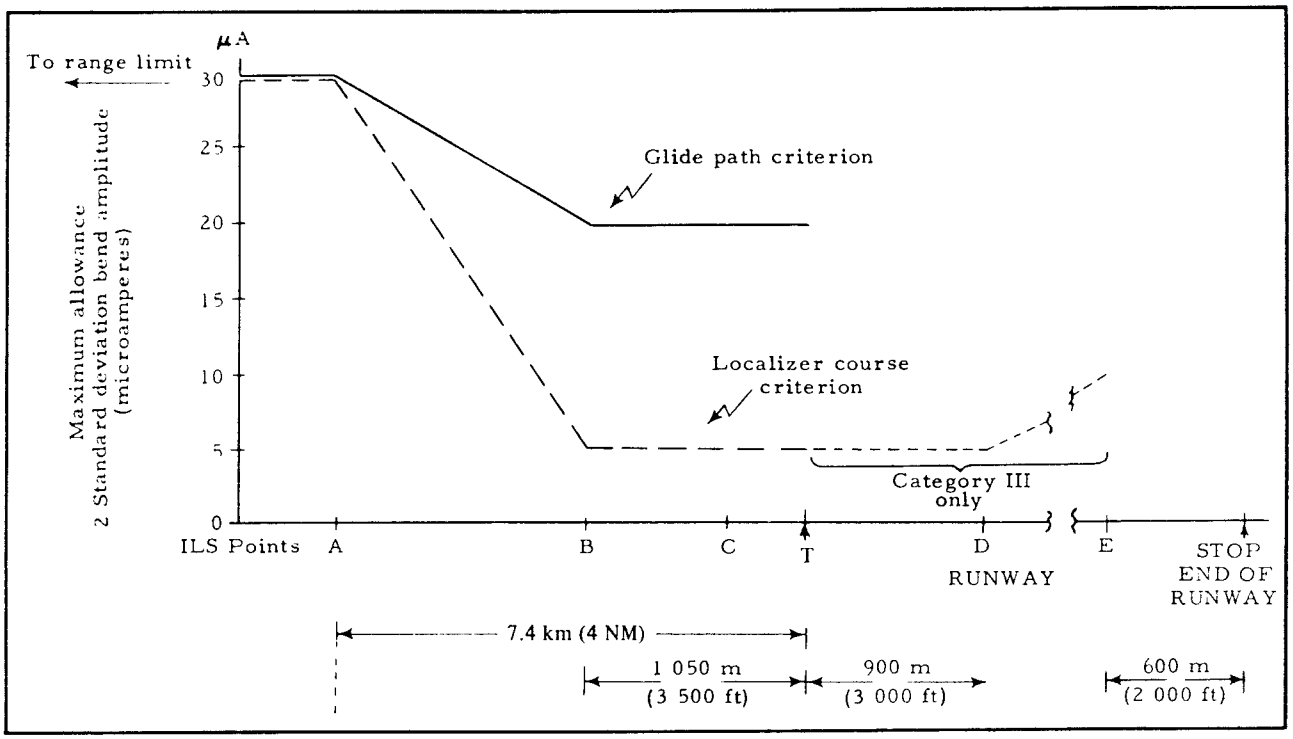


Figure C-1. Categories II and III localizer course and glide path maximum bend amplitude criteria

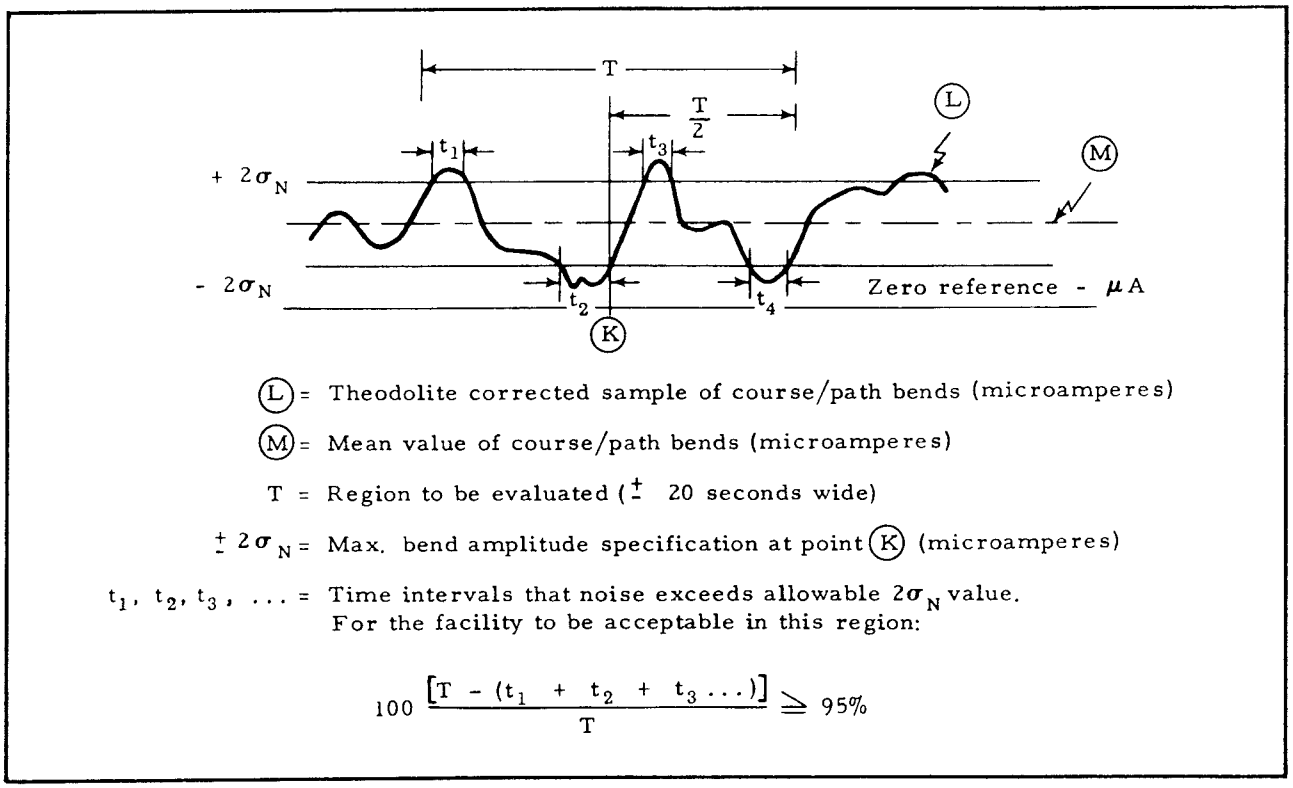


Figure C-2. Evaluation of course/path bend amplitude

course structure (Part I, 3.1.3.4) and ILS glide path structure (Part I, 3.1.4.4), 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 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,

$$100 \frac{[T - (t_1 + t_2 + \ldots .)]}{T} \geq 95\%$$

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 below).

2.1.7 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 total time constant (in seconds) for the receiver DDM output circuits and associated recording equipment of 27/V, where V is the velocity in km/h of the aircraft or ground vehicle as appropriate.

2.1.8 *Monitor systems.* Available evidence indicates that performance stability within the limits defined in Part I, 3.1.3.6, 3.1.3.7 and 3.1.5.6., i.e. well within the monitor limit, can readily be achieved.

The choice of monitor limits is based on judgement, backed by a 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 Part I, 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.

Following are some general guidelines for the design, operation and maintenance of monitor systems to meet the requirements in Part I, 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, birds, etc;

   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) above.

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.

2.1.9 *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. Paragraphs 3.1.2.7, 3.1.2.7.1 and 3.1.2.7.2 of Part I specify the conditions under which radiation by localizers not in operational use may be permitted.

2.1.10 *ILS multipath interference due to large reflecting objects and movements on the ground*

2.1.10.1 The occurrence of interference to ILS signals is dependent on the total environment around the ILS antennas, and the antenna characteristics. The environment, for purposes of developing protective zoning criteria, can be divided into two types of areas, the critical areas and the sensitive areas. The critical area is an area of defined dimensions about the localizer and glide path where vehicles, including aircraft, will cause unacceptable disturbances to the ILS performance. The sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, may affect the ILS performance.

2.1.10.2 An illustrative example of the minimum dimensions of the control areas for a typical ILS, based on experience, is shown in Figures C-3 and C-4. However, some types of ILS may require critical areas different from these minimum dimensions, and where there is doubt, the critical areas should be determined in consultation with the appropriate authority, taking into account the characteristics of the equipment, or if necessary, by experimentation. It is necessary to restrict the entry of vehicles and the taxiing or parking of aircraft within these ILS critical areas during Categories I, II and III operations. The critical area determined for each localizer and glide path should be clearly marked. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical areas to ensure adequate control of vehicle and aircraft ground movements. For all Categories II and III — ILS installations it would be advisable to have critical areas within the aerodrome boundaries so that adequate control can be exercised, but if critical areas fall outside the aerodrome boundaries, it is essential that the co-operation of appropriate authorities be obtained to ensure adequate control.

2.1.10.3 The size of the sensitive area depends on a number of factors including the type of ILS antenna, the topography, 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.

2.1.10.3.1 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.

2.1.10.3.2 In the case of the glide path, experience has shown that any object penetrating a surface above the horizontal plane of the glide path antenna and within azimuth coverage of the antenna must be considered as a possible source of unacceptable 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.

2.1.10.3.3 Control needs to be exercised over sensitive areas to prevent the entry of aircraft and vehicles which will cause unacceptable interference to the ILS signals.

2.1.10.4 Computer or model techniques can be employed to calculate the probable extent of ILS disturbance caused by objects. These methods may be needed to predict the consequences of proposed construction, or of proposals for the parking or taxiing of large aircraft.

2.1.10.5 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 AGA restrictions with regard to obstruction heights.

2.1.10.6 Modern directional localizers and glide path antennas, having properties additional to those of standard antennas, will tend to reduce the probability of multipath degradation to the ILS by large structures on or surrounding an airport, and therefore should be considered at all physically dense locations where the standard antennas cannot meet the requirement. Where an ILS has been installed and found satisfactory, computer and simulation techniques can be employed to calculate the probable extent of ILS disturbance which may arise as a result of proposed new construction.

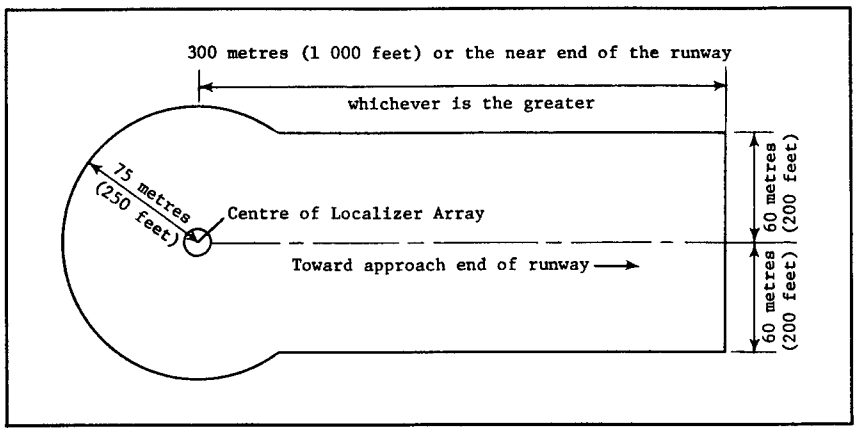


Figure C-3. Typical minimum localizer critical area

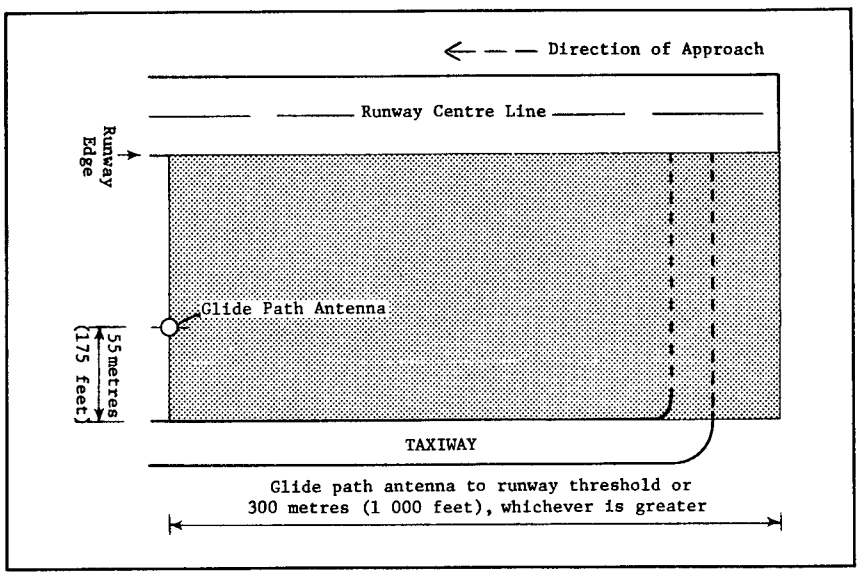


Figure C-4. Typical minimum glide path critical area

2.1.11 *Guidance on operational aspects of improving the performance of the ILS localizer in respect to bends*

2.1.11.1 *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.

2.1.11.2 *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.

2.1.11.3 *Disadvantages of methods of effecting improvements mentioned above*

2.1.11.3.1 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.

2.1.11.3.2 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:

1) Orientation information from the localizer in the sector in which radiation is limited will no longer be available or will be unreliable.

2) 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.

3) 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.

4) The loss of the back course.

2.1.11.3.3 In respect to 1), 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 2), 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.

2.1.11.3.4 The disadvantage indicated in 3) 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.

2.1.11.3.5 The loss of the back course indicated in 4) 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.

2.1.11.4 *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 should be identical with those specified in this Annex 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.

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 Part I, 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.

2.1.11.5 *Further possibilities.* If the disadvantages arising from the use of the restricted coverage and modified signal characteristics discussed in 2.1.11.3 above are unacceptable, possibilities exist through the addition of equipment 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 of high traffic density.

2.2 ILS airborne receiving equipment

Note.— The specified tolerances are those considered necessary to achieve the operational objective and include allowances, where appropriate, for:

a) variation of relevant ground system parameters within the limits defined in Part I, 3.1;

b) variation of aircraft environment;

c) measurement error; and

d) deterioration in service between maintenance periods.

The words "receiving equipment" as used in this section, include the receiver itself, the antenna(s) and the necessary inter-connexions in the aircraft.

2.2.1 *General*

2.2.1.1 In order to ensure consistent and reliable operation, the output characteristics of the receiver in respect of course line (centring) and course width (deflection) should be maintained to a degree of accuracy appropriate to the operational objective. Attention is directed towards the need to take into account the variable conditions that may affect such accuracy.

2.2.1.2 Furthermore, in order to ensure that a constant course width is realized by all users of the ILS system, it is necessary to standardize the over-all gain of the localizer receiver. Similar considerations apply in the case of the glide path receiver.

2.2.2 *Localizer receiver audio gain adjustment*

2.2.2.1 The audio gain of the receiver should be such that, with a radio frequency input of 1 000 microvolts modulated 20 per cent by a 90 Hz tone and 20 per cent by a 150 Hz tone, a zero indication is achieved and that, upon a simultaneous increase in one component of 4.65 per cent (i.e. to 24.65 per cent) and a decrease in the other component of 4.65 per cent (i.e. to 15.35 per cent), there is a proportional deflection of 3/5 of the full course width indication but not less than 9.5 mm along its scale. This gain adjustment is to be made with the normal power supply voltage encountered under airborne operating conditions.

2.2.3 *Localizer receiving equipment centring tolerance*

2.2.3.1 To obtain the operational objectives associated with ILS Performance Categories I, II and III and to assure the safe operation of aircraft within the obstacle clearance surfaces, the centring error of the receiving equipment, operating within all the likely aircraft environmental conditions and receiving a zero signal (DDM) within the limits of the ground equipment radio frequency modulation characteristics and identification tolerances, as specified in Part I, 3.1.3 and with an RF field strength of 90 microvolts per metre (minus 107 dBW/m²), should not exceed the following limits with a 68 per cent probability:

Category I: 4.66 per cent of the full course width indication (0.0072 DDM)

Category II: 2.33 per cent of the full course width indication (0.0036 DDM)

Category III: 1.66 per cent of the full course width indication (0.00258 DDM)

Note.— These requirements should also be met at larger field strengths up to the maximum field strength likely to be encountered in operational service.

2.2.4 *Localizer course displacement sensitivity (deflection) tolerance*

2.2.4.1 When the receiver audio gain has been adjusted in accordance with 2.2.2 above, and with an increase in one modulation tone of the audio frequency input signal of 4.65 per cent with respect to the nominal value (i.e. 24.65 per cent) and a simultaneous decrease of the other component by 4.65 per cent with respect to the nominal value (i.e. 15.35 per cent), the indicated deflection signal should not vary more than plus or minus 0.019 DDM from the nominal value at a signal strength of 90 microvolts per metre (minus 107 dBW/m²) up to the maximum field strength likely to be encountered in operational service.

Note.— See 2.2.5 below in respect to signal levels.

2.2.5 *Localizer receiving system minimum signal level sensitivity*

2.2.5.1 The sensitivity of the localizer receiving equipment should be such that in a high percentage of cases, the receiver should indicate a usable signal and a substantially steady indication in the presence of the minimum field strength specified in Part I, 3.1.3.3.2 (40 microvolts per metre or minus 114 dBW/m²).

Note 1.— The maximum signal level likely to be encountered under 2.2.3 and 2.2.4 above is 500 microvolts. Signal levels on the order of 5 000 microvolts may be encountered in the near vicinity of the transmitter (e.g. when flying over the localizer during a missed approach, or when the localizer is used for rollout or take-off guidance).

Note 2.— The two levels of sensitivity addressed in 2.2.4 and 2.2.5 above ensure:

a) a high quality output such as is necessary for approach purposes; and

b) an output of lesser quality adequate for operational usage of the facility in other parts of the coverage volume.

Note 3.— The proper operation of the localizer receiving system in the presence of the specified minimum field strength should occur independent of the orientation of the aircraft longitudinal axis in the horizontal plane when the aircraft is exposed to roll angles of 20 degrees and pitch angles of 10 degrees.

2.2.6 *Localizer course displacement linearity*

2.2.6.1 The receiver output course displacement signal should be a substantially linear function of the DDM of the receiver input signal. For any input over the range of plus or minus 0.155 DDM, and for any RF signal level likely to be

encountered in operational service, the displacement sensitivity should not depart from the nominal DDM/deflection ratio defined in 2.2.2 above by more than plus or minus 20 per cent. Also for an input signal of plus or minus 0.165 DDM or greater, the output must be greater than full course displacement.

Note.— See 2.2.5 above in respect to signal levels.

2.2.7 *Localizer receiver bandwidth*

2.2.7.1 The receiver bandwidth should be such as to provide for the reception of channels having the characteristics defined in Part I, 3.1.3.2.1 after taking suitable account of appropriate receiver tolerances.

2.2.8 *Setting of localizer receiver capture level for automatic flight control*

2.2.8.1 With reference to Notes 1 and 2 of Part I, 3.1.3.7.4, it is desirable to set the localizer capture level of automatic flight control systems not above 0.175 DDM. This would allow high speed aircraft to execute large angle intercepts at operationally desirable distances without experiencing nuisance switching effects, provided the criteria for the ground installation in the above-mentioned paragraph are met.

2.2.9 *Localizer receiver susceptibility to VOR and localizer signals*

2.2.9.1 The receiver design should provide correct operation in the following environment:

a) the desired signal exceeds an undesired co-channel 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 should be designed to meet this requirement.

Note 2.— In some States, a smaller ground station tolerance is used.

2.2.10 *Immunity performance of ILS receiving systems to interference from VHF FM broadcast signals*

2.2.10.1 With reference to the Note of 3.1.4 of Part I, the immunity performance defined there must be measured against an agreed measure of derogation 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 checking of receiving station equipment on bench test 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. An adequate measure of immunity performance may be obtained by the use of a wanted signal level of minus 86 dBm with the DDM adjusted to give standard deflections between 5 and 180 microamps. With these conditions the change in course deflection current due to the interfering signal should not exceed 10 per cent of the standard deflection when the levels quoted in 3.1.4.1 and 3.1.4.2 of Part I are applied. The broadcast signals should be selected from frequencies in the range between 87.5 and 107.9 MHz and should be modulated with the representative broadcast type signal.

Note 1.— The signal level of minus 86 dBm assumes a combined antenna and feeder gain of 0 dB.

Note 2.— The change of 10 per cent quoted above is for the purpose of standardization when checking that receiving station equipment on bench measurements meet the required immunity. In the planning of frequencies, and in the assessment of protection from FM broadcast interference, a value not exceeding this, but in many cases lower, depending on the operational circumstances in individual cases, should be chosen as the basis of the interference assessment.

2.2.11 *Glide path receiver audio gain adjustment*

2.2.11.1 The audio gain of the receiver should be such that, with a radio frequency input of 600 microvolts modulated 40 per cent by a 90 Hz tone and 40 per cent by a 150 Hz tone, a zero indication is achieved and that, upon a simultaneous increase in one component of 5.25 per cent (i.e. to 45.25 per cent) and a decrease in the other component of 5.25 per cent (i.e. to 34.75 per cent), there is a proportional deflection of 3/5 of full course width indication but not less than 9.5 mm along its scale. This gain adjustment is to be made with the normal power supply voltage encountered under airborne operational conditions.

2.2.12 *Glide path receiving equipment centring tolerance*

2.2.12.1 To obtain the operational objectives associated with ILS Performance Categories I, II and III and to ensure the safe operation of aircraft within the obstacle clearance surfaces, the centring error of the receiving equipment, operating within all likely aircraft environmental conditions and receiving a zero signal (DDM) within the limits of the ground equipment radio frequency, and modulation characteristics tolerances as specified in Part I, 3.1.5, and with

an RF field strength of 400 microvolts per metre (minus 95 dBW/m²), should not exceed the following limits with a 68 per cent probability:

Category I: 5.33 per cent of the full course width indication (0.0093 DDM)

Category II: 3.33 per cent of the full course width indication (0.0058 DDM)

Category III: 3.33 per cent of the full course width indication (0.0058 DDM)

Note.— These operational requirements should also be met at larger field strengths up to the maximum field strength likely to be encountered in operational services.

2.2.13 *Glide path course displacement sensitivity (deflection) tolerance*

2.2.13.1 When the receiver audio gain has been adjusted in accordance with 2.2.10 above and with an increase in one modulation tone of the radio frequency input signal of 5.25 per cent (i.e. to 45.25 per cent) and a simultaneous decrease of the other component of 5.25 per cent (i.e. to 34.75 per cent), the displacement signal should not vary more than plus or minus 0.016 DDM from the nominal value at a signal strength of 400 microvolts per metre (minus 95 dBW/m²) up to the maximum field strength likely to be encountered in operational service.

Note.— See 2.2.14 below in respect to signal levels.

2.2.14 *Glide path receiving system minimum signal level sensitivity*

2.2.14.1 The sensitivity of the glide path receiving system should be such that in a high percentage of cases, the receiver should indicate a usable signal and a substantially steady indication in the presence of the minimum field strength specified in Part I, 3.1.5.3.2 (400 microvolts per metre or minus 95 dBW/m²).

Note 1.— The maximum level of signal likely to be encountered under 2.2.12 and 2.2.13 above is 2 500 microvolts. This signal level occurs when the aircraft is at the runway threshold.

Note 2.— The two levels of sensitivity addressed in 2.2.13 and 2.2.14 ensure:

a) a high quality output such as is necessary for approach purposes; and

b) an output of lesser quality adequate for operational usage of the facility in other parts of the coverage volume.

Note 3.— The proper operation of the glide path receiving system in the presence of the specified minimum field strength should occur also if the aircraft longitudinal axis is varied plus or minus 10 degrees in the horizontal plane together with 20 degrees roll about the localizer course line and also plus or minus 10 degrees pitch in the vertical plane about the horizontal plane.

2.2.15 *Glide path displacement linearity*

2.2.15.1 The receiver output glide path displacement signal should be a substantially linear function of the DDM of the receiver input signal. For any input over the range plus or minus 0.175 DDM, and for any RF signal strength likely to be encountered in operational service, the displacement sensitivity should not depart from the nominal DDM/deflection ratio defined in 2.2.11 above by more than plus or minus 20 per cent. For an input signal of 0.185 DDM or greater, the output must be greater than full course displacement.

Note.— See 2.2.14 above with respect to signal levels.

2.2.16 *Glide path receiver bandwidth*

2.2.16.1 The receiver bandwidth should be such as to provide for the reception of channels having the characteristics defined in Part I, 3.1.5.2.1 after taking suitable account of appropriate receiver tolerances.

2.2.17 *Glide path receiver susceptibility to glide path signal*

2.2.17.1 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 glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 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 17 kHz) and receiver frequency tolerance);

c) an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

Note 1.— It is recognized that not all receivers currently meet requirement b); however, all future equipments should be designed to meet this requirement.

Note 2.— In some States, a smaller ground station tolerance is used.

2.2.18 *Localizer and glide path receiver effect from vertical polarization*

2.2.18.1 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.

2.2.19 *Localizer and glide path receiver spurious response*

2.2.19.1 The response (indicator deflection) of the localizer receiver to a 150 Hz 30 per cent modulated RF signal at 110 MHz should be greater than the response to a similarly modulated but 60 dB greater amplitude RF signal varied over 90 kHz to 107.8 MHz and 112.2 MHz to 1 500 MHz. The response of the glide path receiver to a 150 Hz 30 per cent modulated RF signal at 332.0 MHz should be greater than the response to a similarly modulated but 60 dB greater amplitude RF signal varied over 90 kHz to 329.0 MHz and 335.3 MHz to 1 500 MHz.

2.3 Malfunctioning alarm in ILS airborne equipment

2.3.1 Ideally, a receiver alarm system such as a visual mechanical 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 recommended 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 recommended 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.

c) The receiver off-course indication 50 per cent or less of that specified when setting the receiver audio gain adjustment (see 2.2.2 and 2.2.11 above).

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 The ILS reference datum and the ILS glide path angle setting are the primary factors influencing the longitudinal location of the ILS glide path equipment with respect to the threshold.

2.4.2 The lateral placement of the glide path antenna system with respect to the runway centre line should not be 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.

2.4.3 In selecting the ILS glide path antenna location and glide path angle, the aim should be to place the ILS reference datum as close as possible to the appropriate nominal value. The actual selection of the ILS glide path antenna location and glide path angle are governed by a number of factors, including:

a) acceptable rates of descent and/or approach speeds for the type of operations envisaged at the particular aerodrome;

b) the position of obstacles in the final approach area, the aerodrome sector and the missed approach area, and the resulting obstacle clearance limits;

c) technical siting problems.

2.4.4 The selection of the antenna location and the angle, and the resulting ILS reference datum height, will also be affected by:

a) the runway length available;

b) the operating limits envisaged.

Where the application of the foregoing criteria permits, the preferred angle of the ILS glide path would be 3 degrees.

2.4.5 An ILS reference datum and glide path should then be selected, having regard to the foregoing criteria, and the ability of the site to provide the clearance required by the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS, Doc 8168) should be determined by calculation and confirmed, where possible, by flight test.

2.4.6 Where the selected ILS reference datum, the ILS glide path angle and the other relevant equipment characteristics do not provide the required clearances, the following alternative course of action should be investigated:

1) removal of the offending obstacle;

2) selection of an alternative height for the ILS reference datum, taking into account the criteria indicated in 2.4.3 and 2.4.5 above;

3) selection of an alternative acceptable ILS glide path angle;

4) variation of the obstacle clearance limit to cater for the offending obstacle.

2.4.7 To enable more effective use of land adjacent to Category III — ILS glide path sites and to reduce siting requirements 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 Part I, 3.1.5.3.

2.4.8 *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.

2.4.9 *Relationship between siting of glide path antenna and glide path threshold crossing height.* The longitudinal position of the glide path antenna should be selected so as to meet the recommendation made in Part I, 3.1.5.1.4, in respect to the height of the ILS reference datum above the runway threshold. The height of the ILS reference datum above the runway threshold is then a function of the longitudinal position of the glide path antenna, of the longitudinal slope of the glide path reflection plane and of the position of the runway threshold in respect to the glide path reflection plane. This situation is described pictorially in Figure C-5. The longitudinal position of the glide path antenna is then calculated as follows:

$$D = \frac{H + Y}{\tan(\theta + \alpha)}$$

where

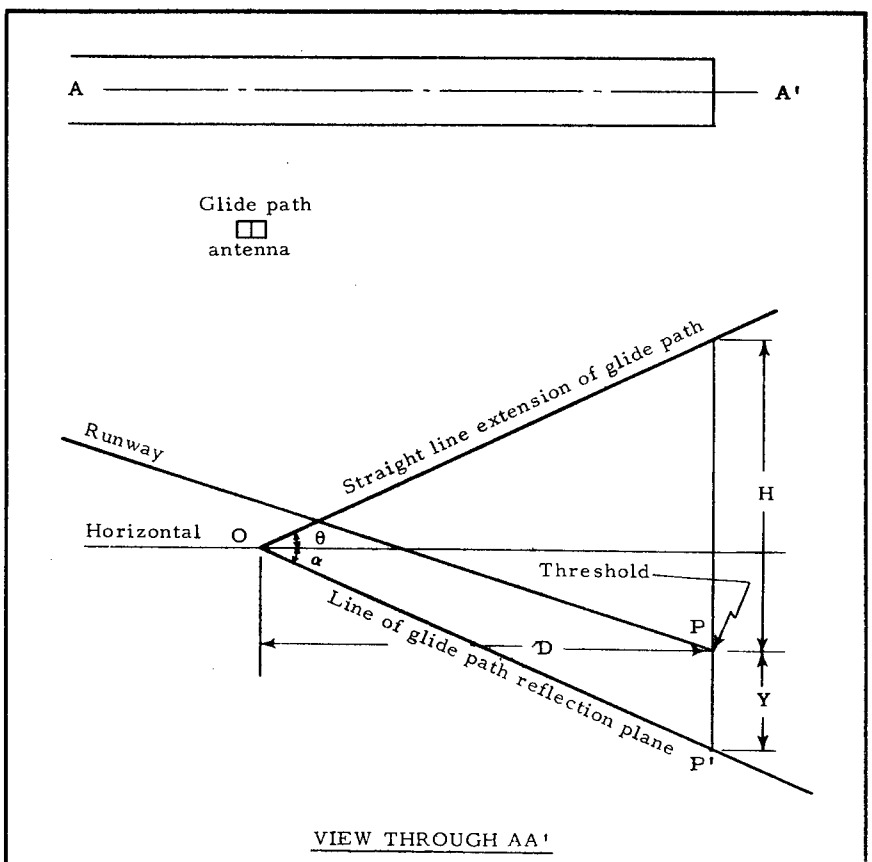
D = the horizontal distance between O and P;

H = the nominal threshold crossing height;

Y = the vertical height of the runway threshold above P′;

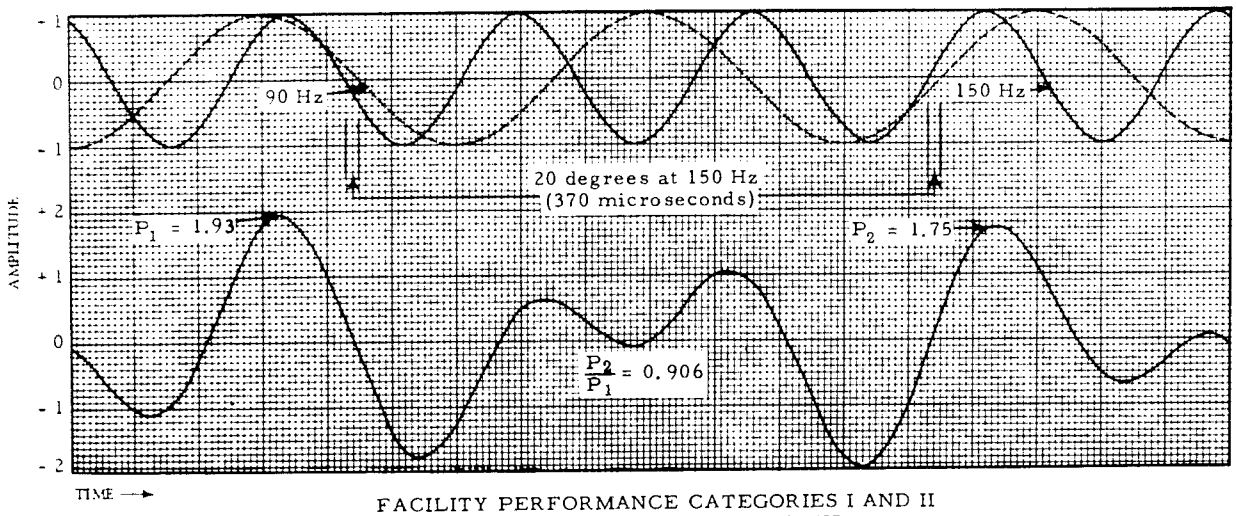
θ = the nominal ILS glide path angle;

α = the longitudinal downslope of the glide path reflection plane.

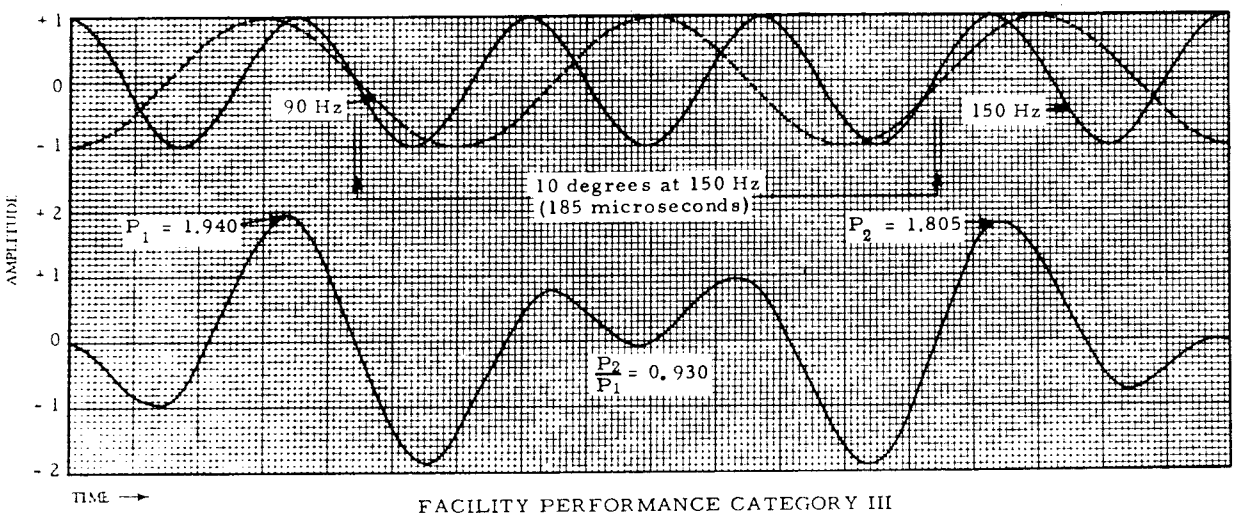


Note.—The line OP′ represents the intersection of the glide path reflection plane and the vertical plane through AA′.

Figure C-5. Glide path siting for sloping runway



FACILITY PERFORMANCE CATEGORIES I AND II
LOCALIZERS AND GLIDE PATHS



FACILITY PERFORMANCE CATEGORY III
LOCALIZERS AND GLIDE PATHS

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 Part I, 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 0.906 and for Category III the ratio should be greater than 0.930.

Figure C-6. ILS wave forms illustrating relative audio phasing of the 90 Hz and 150 Hz tones

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.*

2.4.10 The foregoing guidance material in respect of the longitudinal placement to the glide path antenna in relation to the runway threshold, which takes into account the fact that the runway may not be in the glide path reflection plane, and that the glide path reflection plane may be sloped, is based on geometrical abstractions. The material implicity assumes that the glide path locus in the vertical plane, containing the runway centre line, is a perfect hyperbola; consequently, the glide path extension is implicitly assumed as the asymptote to this hyperbola.

2.4.11 In fact, however, the glide path is often quite irregular. 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.

2.4.12 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 and should be recognized. 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.

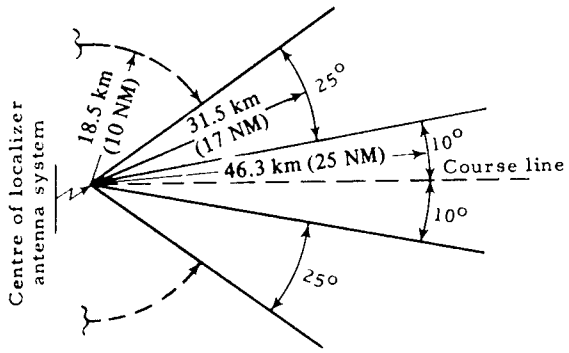
Note.— Further guidance on the measurement of the glide path angle and the achieved ILS reference datum is given in Doc 8071, Volume II.

2.4.13 Part I, 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.

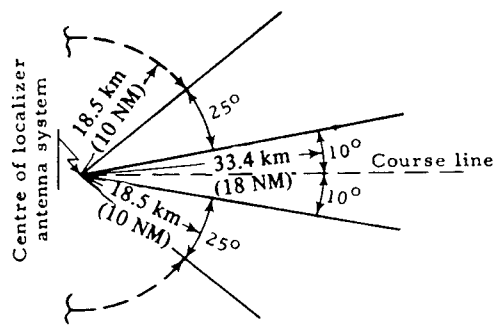
2.4.14 The objective is, therefore, to provide a fly-up signal prior to intercepting the glide path. Although under normal conditions, approach procedures will be accomplished in such a way that glide path signals will not be used below 0.45 θ, or beyond 18.5 km (10 NM) from the runway, it is desirable 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 Part I, 3.1.5.2.1, the provision of a separate clearance monitor and appropriate ground inspection and setting-up procedures.

2.4.15 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 Part I, 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 (Figure C-7 to Figure C-12) illustrating certain of the standards contained in Part I, Chapter 3 of this Annex

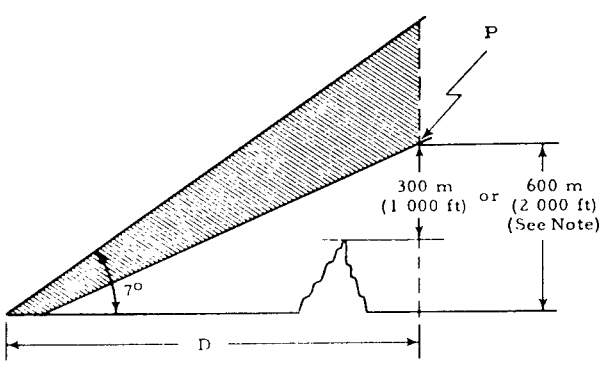


When topographical features dictate or operational requirements and alternative navigation facilities permit, the following coverage may be provided:



Note.– If coverage as prescribed in Part I, 3.1.3.3.1 is required outside the plus or minus 35-degree sector, this shall be provided to 18.5 km (10 NM), as indicated by the broken arc above.

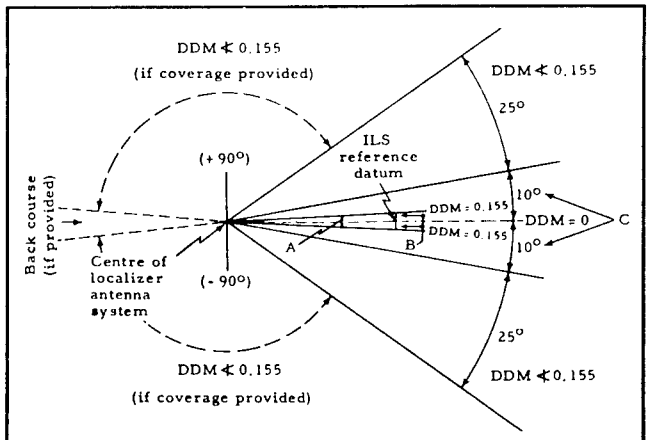
Figure C-7. Localizer coverage in respect to azimuth



D = Distances and azimuths specified in 3. 1. 3. 3. 1

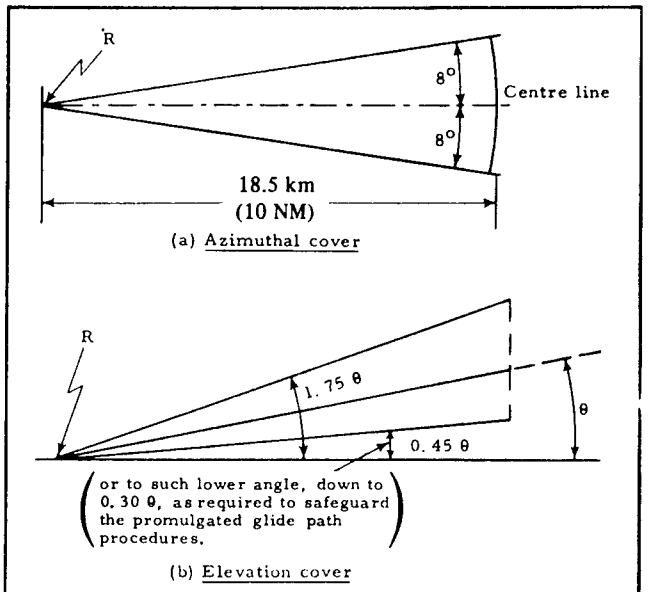
Note.—The point P is either 600 metres (2 000 feet) above the elevation of the threshold, or 300 metres (1 000 feet) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher.

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

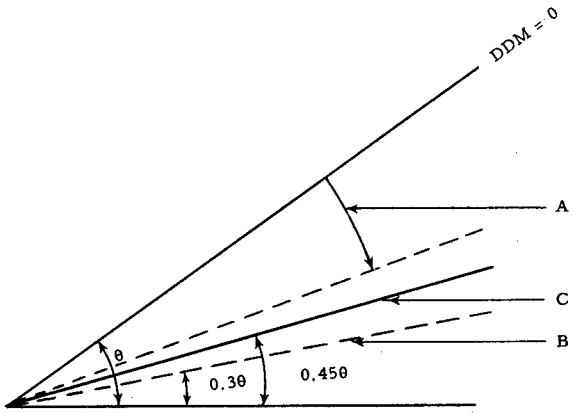
Figure C-9. Difference in depth of modulation and displacement sensitivity



R = Point at which the downward-extended straight portion of the ILS glide path intersects the runway centre line.

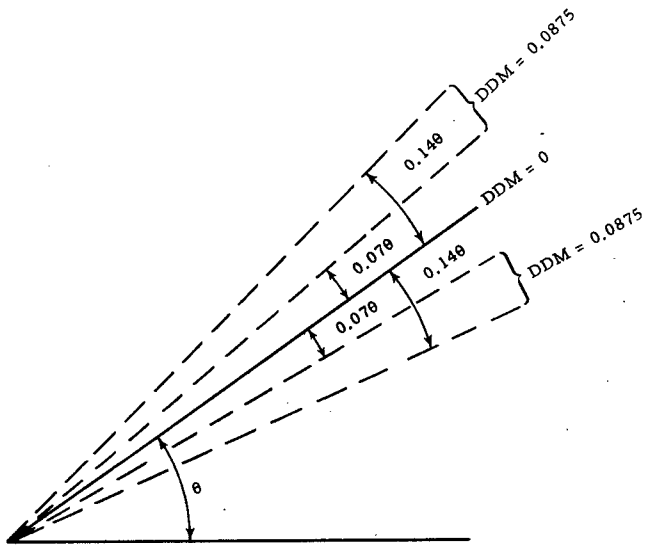
θ = (ILS) glide path angle adjustable between 2° and 4°.

Figure C-10. Glide path coverage

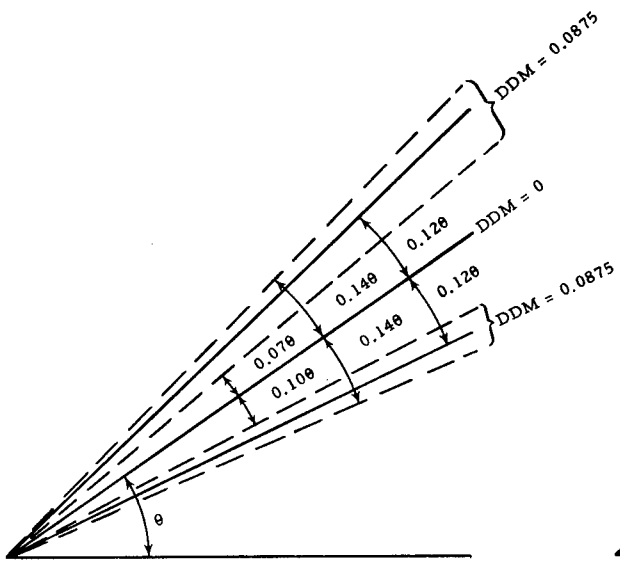


A - DDM increases smoothly to 0.22 DDM
B - ∢ 0.22 DDM down to 0.3 θ
C - If 0.22 DDM is achieved at any angle above 0.45 θ, the DDM value shall not be less than 0.22 at least down to 0.45 θ, or to such lower angle, down to 0.30 θ, as required to safeguard the promulgated glide path interception procedure.

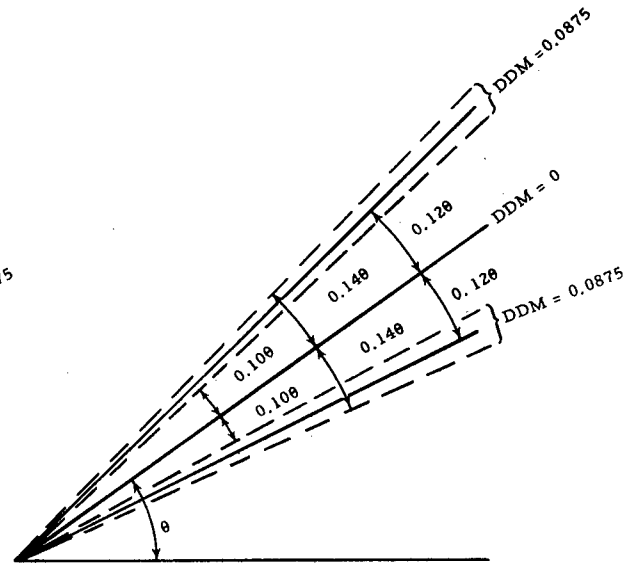
DDM characteristics below glide path
(All categories)



CATEGORY I



CATEGORY II



CATEGORY III

θ = Nominal glide path elevation angle - adjustable between 2° and 4°.
(Broken lines show limits between which the DDM of 0.0875 is to be realized for Categories I, II and III.)

Note.– Figure C-11 depicts the tolerances for the radiated space pattern specified in Part I, 3.1.5.6; however, this space pattern should not be interpreted as being representative of any one particular ground equipment. In this connexion, it should be noted that there are several known types of ILS glide path ground equipment having different characteristics but which can satisfy the requirements of Part I, 3.1.5.6. Therefore, wherever there is a requirement to know the tolerances applicable to a specific equipment, reference should be made to the manufacturer's technical data rather than the ICAO systems specification.

Figure C-11. Glide path — Difference in depth of modulation

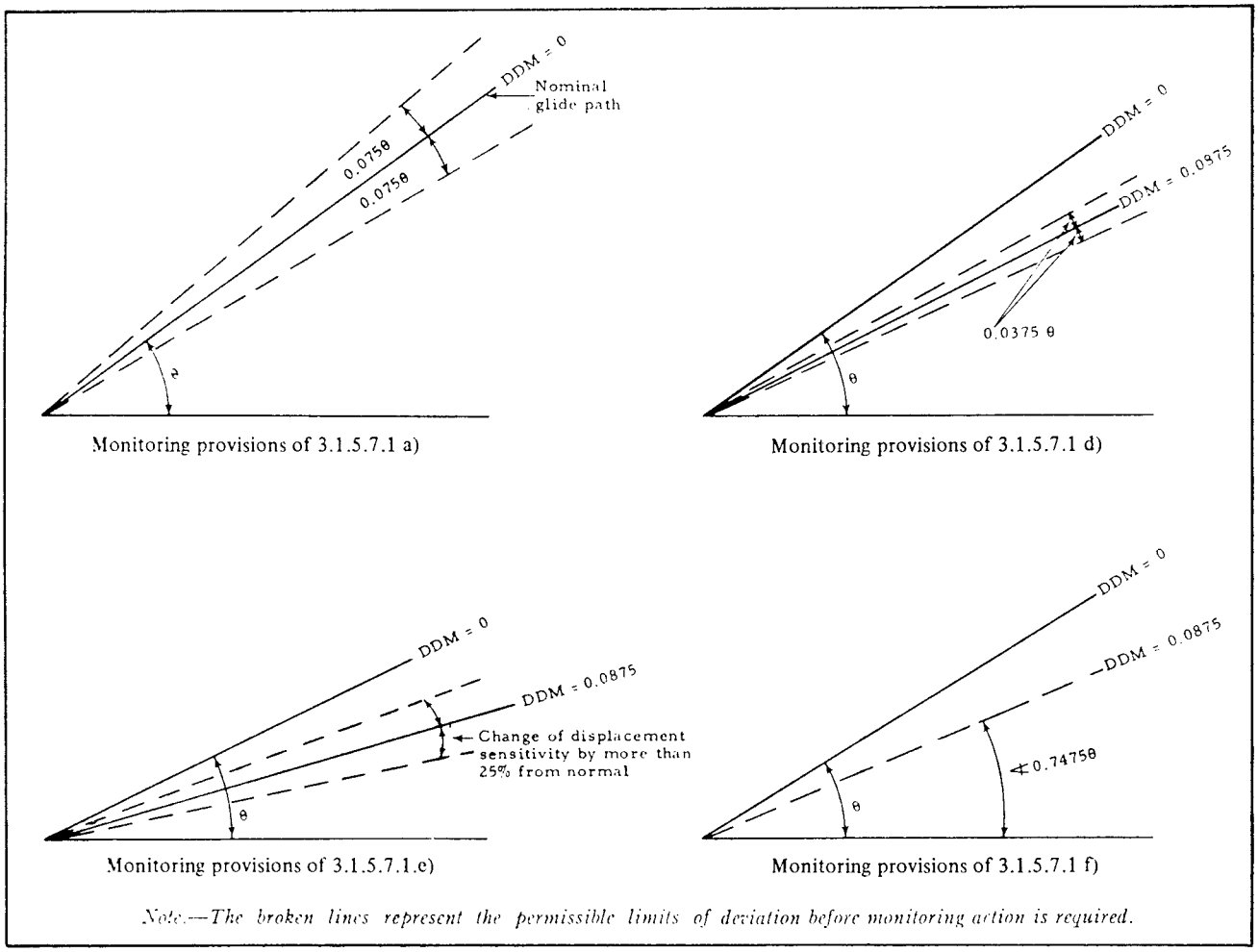


Figure C-12. Glide path monitoring provisions

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. Should there be 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.

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, should 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 should recognize the necessity to site 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.

2.6.2.1.2 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.

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 Part I, 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 below.

Example: Referring to Part I, 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 coverage may be achieved by using two composite radiation field patterns on different carrier frequencies spaced within the localizer frequency channel. One field pattern gives accurate course and displacement indications within the front course sector; the other field pattern provides ILS indications outside the front course sector to meet the coverage requirements in Part I, 3.1.3.3 and 3.1.3.7. 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 and to the coverage limits specified in Part I 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 To minimize further the risk of errors if the ratio of the two radiated signals falls below 10 dB, the difference in alignment of the nominal course lines from the two signals should be not more than 0.2 degree.

2.7.4 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.

2.8 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. 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. 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.

2.8.1.4 It is seen that various operational requirements correspond to varied objectives of integrity and continuity of service. Paragraph 2.14 below identifies and describes four levels of integrity and continuity of service.

2.8.2 *Guidance material concerning the achievement and retention of integrity and continuity of 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 It is especially important that monitors be designed to provide fail-safe operation through compliance with the Standards of Part I, 3.1.3.11.4 and 3.1.5.7.4. This often requires a rigorous design analysis. Monitor failures otherwise may permit the radiation of erroneous signals. Some of the possible conditions which might constitute a hazard in Operational Performance Categories II and III are:

a) an undetected shift of course line significantly outside the monitor limits for localizer and glide path;

b) an undetected fault that significantly changes the course width and glide path sensitivity;

c) an undetected fault causing slow cyclic movements of the course, producing apparent course bends as seen by the approaching aircraft significantly exceeding in amplitude the figures specified in Part I, 3.1.3.4.2 for the localizer and Part I, 3.1.5.4.2 for the glide path between ILS points "B" and "T".

2.8.2.4 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 by carrying out maintenance checks on the monitor system performance at intervals which are determined by the design analysis. Such an 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) $I = 1 - P$

$$P = \frac{T_1 T_2}{\alpha_1 \alpha_2 M_1 M_2} \quad \text{when } T_1 < T_2$$

where

I = integrity

P = the probability of a concurrent failure in transmitter and monitor systems resulting in erroneous undetected radiation

M_1 = transmitter 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:

$$(2) \quad P = \frac{T_2^2}{\alpha_1 \alpha_2 M_1 M_2}$$

2.8.2.5 With regard to integrity, 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 The MTBF 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 during manufacture. It is essential to ensure that equipment is operated within the environmental conditions specified by the manufacturer. The manufacturer should be requested to provide the details of the design to enable the MTBF and continuity of service to be calculated. It is recommended that the equipment MTBF should be confirmed by evaluation in an operational environment to take account of the impact of operational factors, i.e. airport environment, inclement weather conditions, power availability, quality and frequency of maintenance, etc. For integrity and continuity of service levels 2, 3 or 4 the evaluation period should be sufficient to determine achievement of the required level with a high degree of confidence.

2.8.2.7 Continuity of service performance may also be demonstrated by means of MTBO (mean time between outages) where an outage is defined as any unanticipated cessation of signal-in-space. It is calculated by dividing the total facility up-time by the number of operational failures. MTBF and MTBO are not always equivalent, as not all equipment failures will necessarily result in an outage, e.g. an event such as a failure of a transmitter resulting in the immediate transfer to a standby transmitter. The minimum MTBO values expected for the continuity of service in 2.14 below have been derived from several years of operational experience of many systems. To determine whether the performance record of an individual ILS system justifies its assignment to levels 2, 3 or 4 requires a judicious consideration of such factors as:

1) the performance record and experience of system use established over a suitable period of time;

2) the average achieved MTBO established for this type of ILS; and

3) the trend of the failure rates.

An assigned designation should not be subject to frequent change.

2.8.2.8 During the equipment evaluation, and subsequent to its introduction into operational service, records should be maintained of all equipment failures or outages to confirm retention of the desired continuity of service.

2.8.2.9 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 or 4. The localizer facility consists 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) monitoring of operation within the specified limits of the main transmitter and antenna system by means of majority voting among redundant monitors;

b) monitoring the standby equipment.

2.8.2.9.1 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.

2.8.2.9.2 An identical monitoring arrangement to the localizer is used for the glide path facility.

2.8.2.9.3 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.

2.8.2.9.4 In the above example the equipment would include provision to facilitate monitoring system checks at intervals specified by the manufacturer, consequent to his 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 Part I, 3.1.3.11.3 or 3.1.5.7.3.

2.8.2.9.5 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.

2.8.2.9.6 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 if the failure affects operational use.

2.8.2.10 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.

2.8.2.11 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 2.1.10 above. With regard to radio interference it may be necessary to confirm periodically that the level of interference does not constitute a hazard.

2.8.2.12 A far field monitor can provide additional protection by providing a warning against the extremely remote probability of the radiation of false information from a localizer facility, as indicated in 2.8.5 below.

2.8.2.13 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 Part I, 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.

2.8.2.14 An equipment arrangement similar to that at 2.8.2.9 above, but with no transmitter redundancy, and the application of the provisions outlined in 2.8.2.11, 2.8.2.12 and 2.8.2.13 above, would normally be expected to achieve the objectives for integrity and continuity of service level 2.

2.8.2.15 An analysis of the factors involved in different types of operation allows the determination of desired values for the integrity, expressed in terms of the probability in any one landing, to be determined from the allowable global risk factor criterion. See 2.14.2 c) below.

2.8.3 The stringent requirement for integrity and high continuity of service essential for Category III operations requires the use of ILS Facility Performance Category III equipment having adequate assurance against failures. A failure is taken to be performance outside the monitor system tolerances specified in Part I at 3.1.3.11 for Category III localizers and 3.1.5.7 for Category III glide paths. Reliability of ground equipment operation must be very high, so as to ensure that safety during the critical phase of approach and landing is not impaired by a ground equipment failure when the aircraft is at such a height or attitude that it is unable to take safe corrective action. A high probability of performance within the specified limits has to be ensured. Facility reliability in terms of mean time between failure (MTBF) clearly has to be related on a system basis to the probability of failure which may affect any characteristic of the total signal-in-space. One analysis has shown that the continuity of service of an ILS installation used for Category IIIA operations should be such that the localizer facility and the glidepath facility each have an MTBF of 4 000 hours or more. The system must ensure the highest degree of protection against failure of the monitors to detect a failure in performance of the ground equipment. It is suggested that States endeavour to achieve reliability with as large a margin as is technically and economically reasonable.

2.8.3.1 The following configuration is an example of a redundant arrangement suitable for Category III operations. The localizer facility consists of two continuously operating transmitters, one connected to an antenna load. With these transmitters is associated a monitor system performing the following functions:

a) monitoring of operation within the specified limits of the main transmitter and antenna system by means of a majority voting among redundant monitors;

b) monitoring the standby equipment.

2.8.3.1.1 Whenever the monitor system rejects one of the equipments the facility will no longer have Category III status because the probability of cessation of signal consequent on failure of other equipment will be too high. This reversion to a lower category is automatically indicated at remote locations.

2.8.3.1.2 An identical monitoring arrangement is used for the glide path facility.

2.8.3.1.3 To reduce mutual interference between the main and standby transmitters, any stray radiation from the latter should be at least 50 dB below the carrier level of the main transmitter measured at the antenna system.

2.8.3.2 The highest order of protection is required against the consequence of undetected monitor system failures. This should be achieved by careful design to reduce the probability of such occurrences to a low level and by carrying out maintenance checks on the monitor system performance at intervals which are determined by the design analysis.

2.8.4 Additional guidance material applicable to Categories II and III — ILS localizer and glide path ground equipments is given below.

2.8.4.1 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. It is recommended that the equipment reliability should be established by evaluation before introduction into Categories II and III service. Design analysis should verify the predicted performance of the equipment.

2.8.4.2 Interruption of facility operation due to primary power failures should be 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 final phases of an approach. Therefore, the standby supply should have adequate capacity to sustain service for at least 2 minutes.

2.8.4.3 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.

2.8.5 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, may be substantially monitored by using a far field monitoring system built around a suitable receiver(s), installed under the approach path. It may be used as a passive monitor or as an executive monitor.

2.8.5.2 To meet the very stringent ILS reliability objectives for low minima operations, described in this section, 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. Therefore, if the far field monitor is to be used as an executive monitor, means must be adopted to prevent such temporary interference effects from interrupting localizer service; methods of achieving this are covered in 2.8.5.4 below. 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 and its environs.

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 preventing undesired interruption of localizer service when the far field monitor is used to provide an executive alarm are as follows:

a) incorporation of a time delay within the system adjustable from 30 to 120 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 deviation 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. When used for Category III operations, the far field monitor system design should be consistent with the over-all requirements for integrity that are necessary for Category III — ILS.

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 Part I, 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.

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 Part I, 3.1;

b) the extent of compliance with the provisions in Part I, 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.

2.13.4 Where two separate ILS facilities serve opposite ends of a single runway, an interlock should ensure that only the localizer serving the approach direction in use should radiate.

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 Part I, 3.1.3 and 3.1.4;

b) T, D or E: these characters define the ILS points to which the localizer conforms to the course structure criteria given at Part I, 3.1.3.4.2, except the letter T which will designate the runway threshold; and

c) 1, 2, 3 or 4: this number indicates the level of integrity and continuity of service given in Table C-2.

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	$1 - 10^{-6}$ 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.

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 basically relates to the needs of Category II operations and is a desirable 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 basically relates to the needs of Category IIIA operations or Category III operations with a decision height and is a desirable objective for equipment supporting Category II 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, lights, etc.

3. Material concerning VOR

3.1 Guidance relating to VOR effective radiated power (ERP) and coverage

3.1.1 The field strength specified at Part I, 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 100 dBW is obtained at 118 MHz with a power density of minus 107 dBW/m²; minus 107 dBW/m² 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 Nominal values of the necessary ERP to achieve a field strength of 90 microvolts per metre (minus 107 dBW/m²) are given at Figure C-13. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the effective radiated power. 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 ERP.

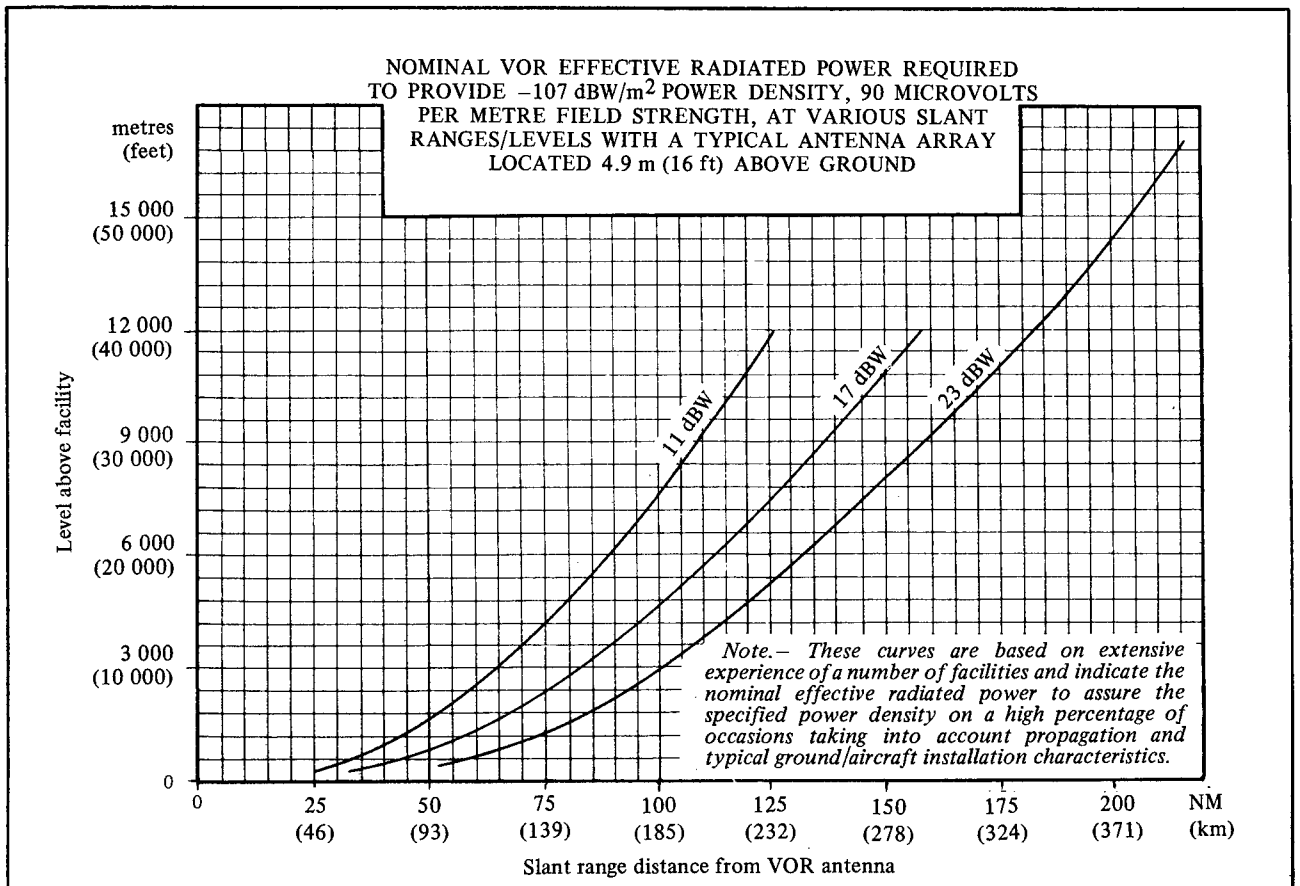
Note.— The nominal effective radiated powers, expressed as a function of level and range, are based upon consideration of basic theoretical data from various sources (such as CCIR, NBS, etc.) modified empirically to reflect typical operational experience.

3.1.3 The use of Figure C-13 is illustrated by the following examples. In order to achieve the necessary field strength at 342 km (185 NM)/12 000 m (40 000 ft), 300 km (162 NM)/12 000 m (40 000 ft), and 166.5 km (90 NM)/6 000 m (20 000 ft), nominal effective radiated powers of plus 23 dBW, plus 17 dBW and plus 11 dBW respectively are required.

3.1.4 In order to facilitate frequency and equipment planning, wherever practicable, ERP categories corresponding to plus 23 dBW, plus 17 dBW and plus 11 dBW should be employed. These ERP values should be indicated during Regional Planning Activities.

3.1.5 A VOR having an ERP of plus 23 dBW approximates to a VOR previously referred to in Annex 10 as Category A (transmitter power 200 W). Possible relationships between ERP and transmitter output powers are illustrated by the following examples:

	Example I	*Example II*
Transmitter power	+23 dBW	+18 dBW
Ground transmission line loss	−2 dB	−1 dB
Antenna gain relative to an isotropic antenna	+2 dB	+6 dB
ERP	+23 dBW	+23 dBW



Note.— These curves display coverage versus power only. For frequency planning guidance, refer to 3.4 of Attachment C to Part I.

Figure C-13

Similarly, a VOR having an ERP of plus 17 dBW approximates to a VOR previously referred to in Annex 10 as Category B (transmitter power 50 W). Possible relationships between ERP and transmitter output powers are illustrated by the following examples:

	Example I	*Example II*
Transmitter power	+17 dBW	+10 dBW
Ground transmission line loss	−2 dB	−1 dB
Antenna gain relative to an isotropic antenna	+2 dB	+8 dB
ERP	+17 dBW	+17 dBW

3.1.6 It is recognized that the above ERP categories may achieve a greater coverage than is necessary for some operational requirements. A suitable lesser coverage might be achieved by a VOR facility having an ERP of approximately plus 11 dBW as follows:

	Example I	*Example II*
Transmitter power	+11 dBW	+7 dBW
Ground transmission line loss	−2 dB	−1 dB
Antenna gain relative to an isotropic antenna	+2 dB	+5 dB
ERP	+11 dBW	+11 dBW

3.2 Guidance in respect of siting of VOR

3.2.1 The site should be on the highest ground in the vicinity to obtain the greatest line-of-sight coverage and should be level or should slope away from the station (at a downgrade not exceeding 4 per cent) to a distance of at least 300 m (1 000 ft) and preferably to 600 m (2 000 ft) from the station. The site contours should be circular with respect to the antenna array to a radius of at least 300 m (1 000 ft). The site should be as far removed from wire lines and fences as possible. The height of wire lines and fences should not subtend a vertical angle of more than 1.5 degrees or extend more than 0.5 degree above the horizontal as measured from the antenna array. These limits may be increased by 50 per cent for fences or lines which are essentially radial to the antenna array or which subtend a horizontal angle of no more than 10 degrees. Single trees of moderate size, up to 9 m (30 ft) in height, may be tolerated beyond 150 m (500 ft). No groups of trees should subtend a vertical angle greater than 2 degrees or should be within 300 m (1 000 ft) of the station. Provisions should be made for clearing trees to 600 m (2 000 ft) if it should prove necessary. No structures should subtend a vertical angle greater than 1.2 degrees or should be within 150 m (500 ft) of the station. Wooden structures with negligible metallic content and with little prospect of future metallic additions may subtend vertical angles up to 2.5 degrees.

3.2.2 In mountainous terrain, a mountain-top site will often be preferable. The site should be on the highest accessible hilltop or mountain, the top of which should be graded flat to a radius of at least 45 m (150 ft). On such sites, the antenna system should be installed approximately a half wavelength above ground level in the centre of the graded area and the transmitter building should be beyond the graded area, far enough down the slope to be below optical line of sight from the antenna array. No ground, trees, power lines, buildings, etc. between 45 m (150 ft) and 360 m (1 200 ft) should be within optical line of sight of the antenna array.

3.3 Determination of the effect of "polarization error" on VOR accuracy

3.3.1 As it is not possible to specify as yet the maximum permissible value of the vertically polarized component of the radiation from the VOR, certain flight tests are necessary to determine the effect on the bearing indication accuracy due to the presence of the "polarization errors".

3.3.2 Three methods are available to determine the effects of "polarization errors":

1) 30-degree wing rock;

2) flying 8 tracks over a ground check-point;

3) flying a circle at 30-degree bank.

The first of these methods is designed to measure the polarization errors which occur when an aircraft rolls while flying a given VOR radial. The second method measures the polarization error for eight different aircraft headings when the aircraft is not banked. The third method measures the polarization errors, for all aircraft headings, with the aircraft banked at 30 degrees. The flight tests are as follows:

3.3.3 *30-degree wing rock.* The aircraft is flown on a constant heading towards the VOR station and is banked slowly from plus 30 degrees to minus 30 degrees. The course deviation indicator current is recorded and converted into degrees of course displacement.

3.3.4 *Eight tracks over a ground check-point.* The aircraft is flown over a specific ground check-point on eight different headings displaced by 45 degrees. The course deviation indicator current is recorded and the recording is marked when the aircraft is over the check-point . The indicated bearing on each heading is compared with the indicated bearing when the aircraft is heading towards the VOR station and is over the check-point.

3.3.5 *Circular flight with 30-degree bank.* The aircraft is first headed towards the VOR station over a ground check-point. From this point, it is flown in a circle at constant 30-degree bank. The course deviation indicator current is recorded while the aircraft is flying this circle and converted

into degrees of error from the bearing indicated at the beginning of the procedure when the aircraft is over the check-point. The change of bearing of the aircraft with respect to the VOR station must be subtracted from the course deviation error. The resultant, after receiver error has been eliminated, is assumed to be polarization error.

3.3.6 The polarization tests may conveniently be conducted at an altitude of 300 m (1 000 ft). Flight tests in 3.3.4 and 3.3.5 above may be employed with respect to a check-point which is approximately 33.4 km (18 NM) from the VOR.

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.

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 $D_1 < D_2 + \frac{K}{S}$

Table C-3. Values of geographical separation distances for co-channel operation

Altitude		*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* $D_1 < D_2 + \frac{K}{S}$			
m (ft)	S dB/km (dB/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.

B — *geographical separation (adjacent channel):*

collocation case

$$< \frac{40 - K}{S}$$

non-collocated case

$$> 2\,D_1 - \frac{40 + K}{S}\ \text{km}$$

where $D_1 > D_2 + \frac{K}{S}$

or $> 2\,D_2 - \frac{40 - K}{S}\ \text{km}$

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:

$$> 2\,D_1 - \frac{6 + K}{S}\ \text{km}$$

where $D_1 > D_2 + \frac{K}{S}$

or $> 2\,D_2 - \frac{6 - K}{S}\ \text{km}$

where $D_1 < D_2 + \frac{K}{S}$

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 above 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 3.3.2.2 and 3.3.5.7 of Part I and 4.2.4 of Part II. 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 3.3.2.2 and 3.3.5.7 of Part I and 4.2.4 of Part II, 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 above 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 Part I, 3.5.3.3.5, 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). However, if DME/W facilities are employed, the first adjacent channel minimum separation for the DME/W facilities should be equal to the co-channel separation specified for the VOR. The second adjacent channel minimum separation for DME/W facilities should equal the first adjacent channel separation specified for VOR. 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 below, 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 above, and the VOR receiver characteristic as shown in 3.4.2 above;

b) that the protection ratio for the ILS system and the VOR system is 20 dB as in 2.6.3 above and 3.4.3 above, 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.*

1) 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.

2) 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.

3) 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 above 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 below, 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 Part I, 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), etc.).

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 Part I, 3.3.5, the flags will again become visible in the event of a decrease in the receiver's over-all 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 should be 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 the Note of 3.3.8 of Part I, the immunity performance defined there must be measured against an agreed measure of derogation 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 checking of receiving station equipment on bench test 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 bearing accuracy and flag current. An adequate measure of immunity performance may be obtained by the use of a wanted signal level of minus 79 dBm and a standard VOR modulation. With these conditions the change in bearing indication should not exceed 0.5 degree, corresponding to a change in deflection current of 7.5 microamps when interfering FM broadcast signals with the levels quoted in 3.3.8.1 and 3.3.8.2 of Part I are applied. The broadcast signals should be selected from frequencies in the range between 87.5 and 107.9 MHz and should be modulated with a representative broadcast type signal.

Note 1.— The signal level of minus 79 dBm assumes a combined antenna and feeder gain of 0 dB.

Note 2.— The change of 7.5 microamps quoted above is for the purpose of standardization when checking that receiving station equipment on bench measurements meet the required immunity. In the planning of frequencies and in the assessment of protection from FM broadcast interference, a value not exceeding this, but in many cases lower, depending on the operational circumstances in individual cases, should be chosen as the basis of the interference assessment.

3.7 VOR system accuracy

Note.— Guidance material on the determination of VOR system performance values is also contained in Annex 11, Attachment E.

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 to him.

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 introduce 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:

$$\text{VOR aggregate error} = \sqrt{Eg^2 + Ea^2}$$

$$\text{VOR system use error} = \sqrt{Eg^2 + Ea^2 + Ep^2}$$

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 above, 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 below). 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 above).

VOR pilotage element:

plus or minus 2.5° (95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8 below).

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 below).

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 below).

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 over-all 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 over-all 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, whilst 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 over-all 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 Change-over points for VORs

3.8.1 Guidance on the establishment of change-over points on ATS routes defined by VORs is contained in Annex 11, Attachment E.

4. Precision approach radar system

Figures C-14 to C-18 illustrate certain of the Standards contained in Part I, 3.2 of this Annex.

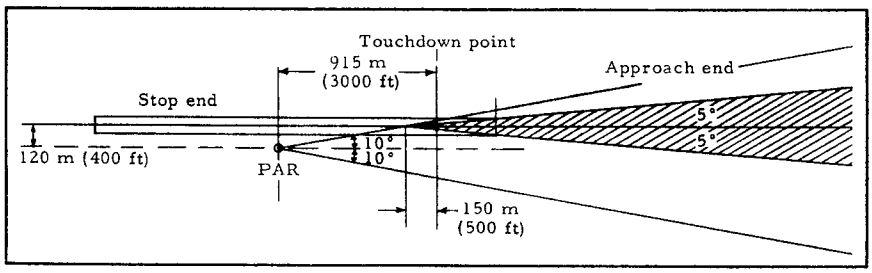


Figure C-14. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

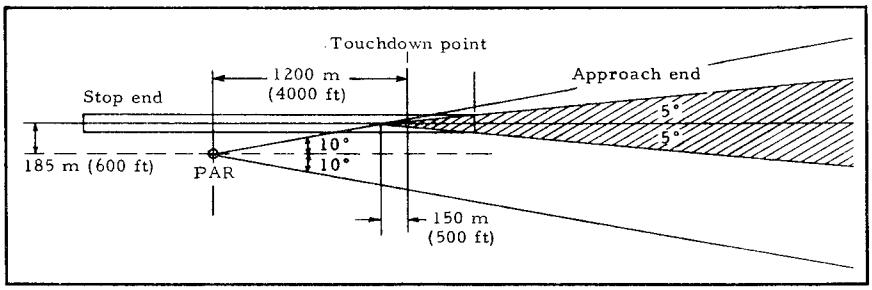


Figure C-15. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

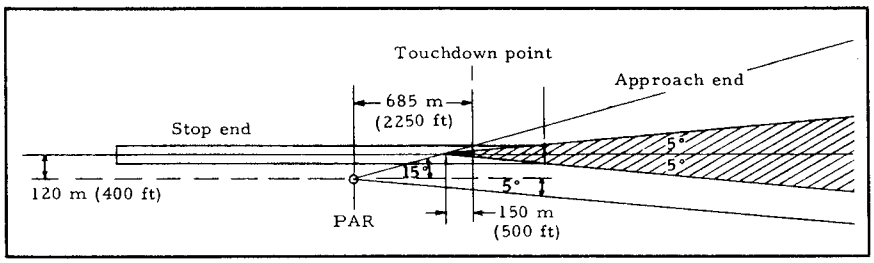


Figure C-16. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan 5 degrees and 15 degrees with respect to QDR of runway

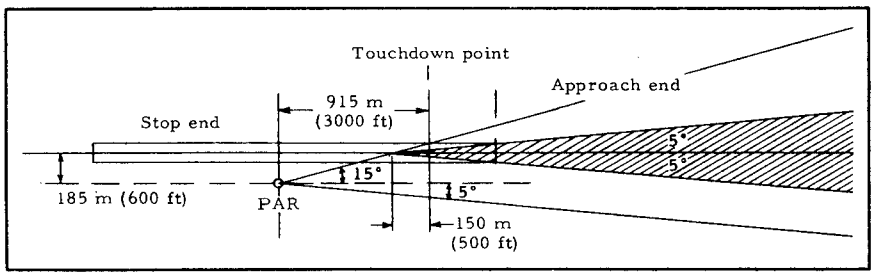


Figure C-17. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan 5 degrees and 15 degrees with respect to QDR of runway

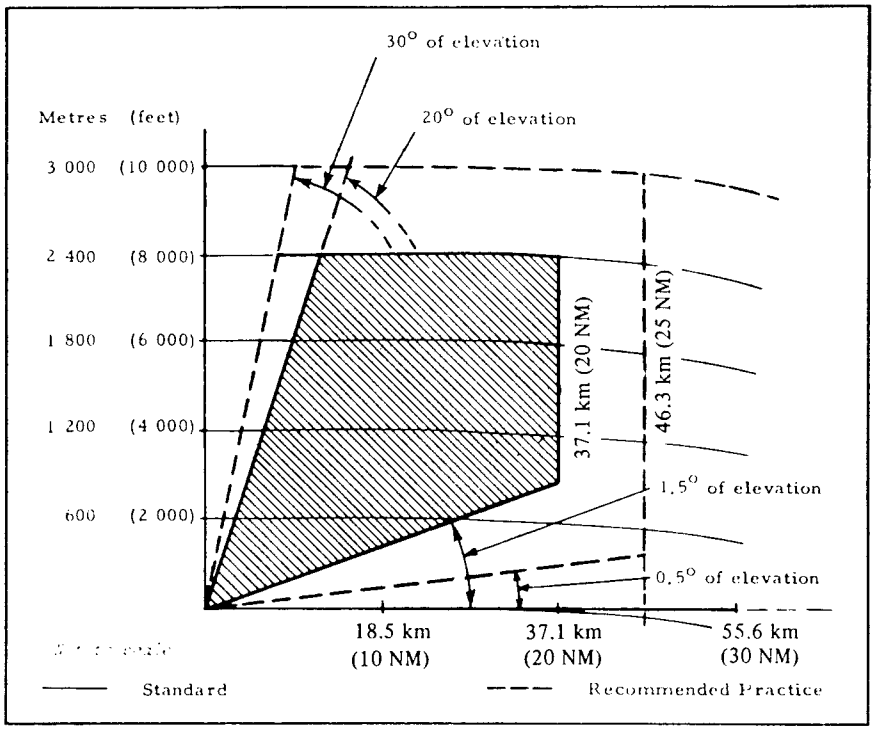


Figure C-18. SRE of precision approach radar system — Vertical coverage on a 15 m² echoing area aircraft

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 below) may be required.

5.1.2 *Z marker beacons.*

a) *Radiating systems.* 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 Part I, 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, Burma, 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 Part I, 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 Part II 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 co-channel 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 co-ordination with the authorities of the other stations likely to be affected (see Part I, 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 below 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:

1) 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;

2) 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, over-all 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 are given in Report 322 of the CCIR, published as a separate booklet.

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 Part I, 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:

1) the power supplied to the antenna of the NDB;

2) the radiation efficiency of the antenna, which varies according to the height of the antenna and other characteristics of the radiating system;

3) 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;

4) the operating radio frequency.

6.2.3.4 The noise admitted by the receiver depends on:

1) the bandwidth of the receiver;

2) 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;

3) 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;

4) 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 Report No. 65 of the VIIIth Plenary Assembly of the CCIR (Warsaw, 1956), and the IXth Plenary Assembly of the CCIR (Los Angeles, 1959) 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 during 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:

Latitude	*Input power to antenna*			
	(a)	*(b)*	*(c)*	*(d)*
	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★

Latitude	*Input power to antenna*			
	(e)	*(f)*	*(g)*	*(h)*
	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:

Latitude	*Input power to antenna*			
	(a)	*(b)*	*(c)*	*(d)*
	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

Latitude	*Input power to antenna*			
	(e)	*(f)*	*(g)*	*(h)*
	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:

1) the distances are given in kilometres, in accordance with ITU practice;

2) 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) above];

3) 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) above. *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*

6.4.2.1 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

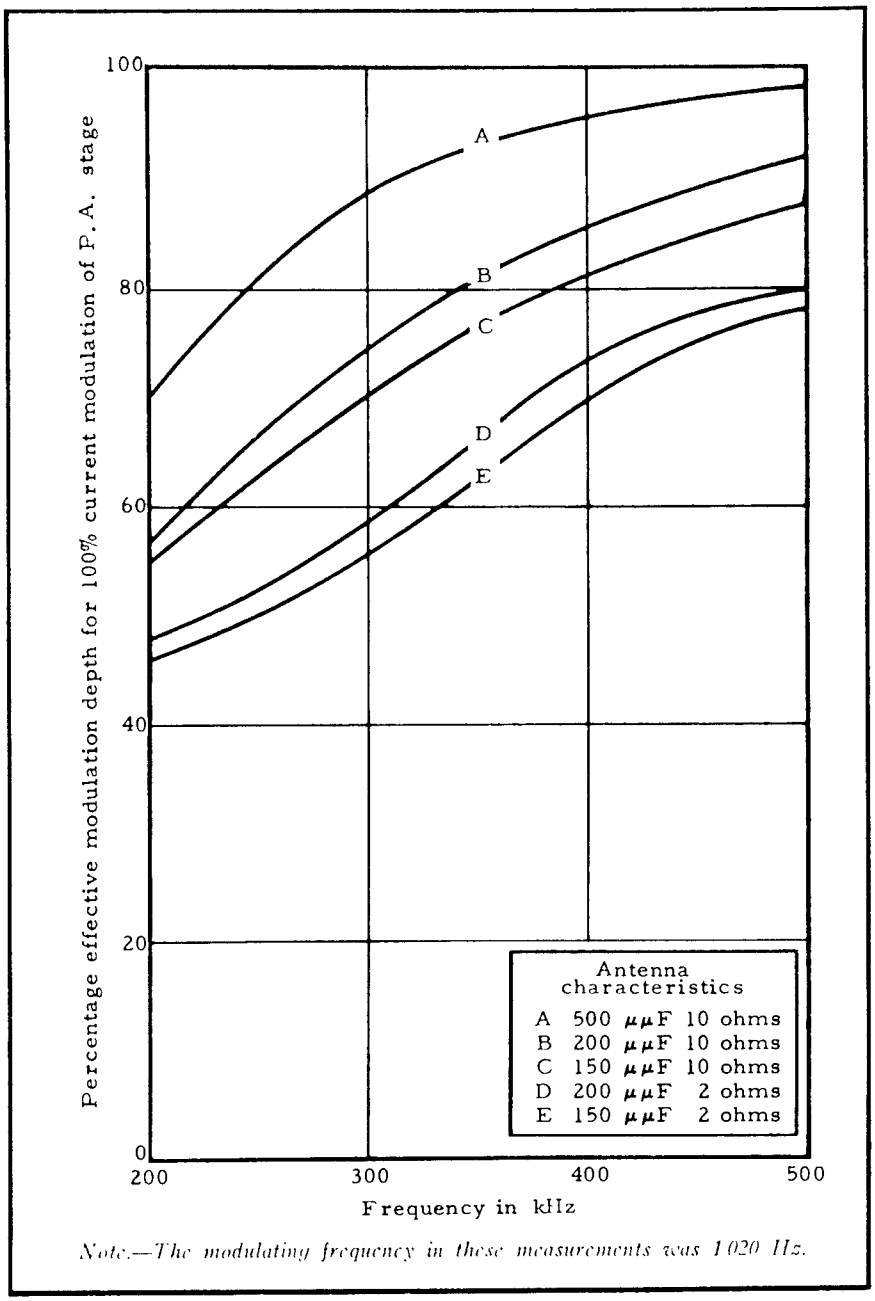


Figure C-19. The effect of antenna Q on the depth of modulation of the radiated signal

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.

6.5 Considerations affecting the choice of the modulating frequency for NON/A2A NDBs

6.5.1 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.

6.6 Guidance material on the testing of NDBs

6.6.1 In the following paragraphs an indication is given of the desirable periodicity for various tests. These figures are intended as only general guidance, it being recognized that many local circumstances will influence a State in establishing its test programmes.

6.6.1.1 *Carrier frequency*

6.6.1.1.1 The carrier frequency should periodically be tested against an accurate standard to ensure that the tolerance specified in Part I, 3.4.4.2, is maintained. A standard such as a crystal controlled frequency meter having an accuracy of 0.001 per cent of the operating frequency is recommended for this purpose.

6.6.1.1.2 This test of carrier frequency stability should be carried out:

a) at least semi-annually for crystal controlled transmitters;

b) at least once a month for non-crystal controlled transmitters.

6.6.1.1.3 If practicable, tests at shorter intervals should be made.

6.6.1.2 *Frequency of the modulating tone*

6.6.1.2.1 The identification frequency requirements are specified in Part I, 3.4.5.4. An audio signal generator calibrated to an accuracy of 0.5 per cent or better at the specified frequency is recommended as a calibration standard.

6.6.1.2.2 This test should be made at least once a month.

6.6.1.3 *Ground wave field strength*

6.6.1.3.1 It is recommended that remote field strength measurements be made using a field strength indicator set capable of checking that the power radiated from an NDB is in accordance with Part I, 3.4.3.

6.6.1.3.2 This test should be carried out at least once a month.

6.6.1.4 *Modulation depth*

6.6.1.4.1 Part I, 3.4.6.2, requires that the depth of modulation of the carrier frequency should be maintained as near to 95 per cent as practicable. Use of an oscilloscope capable of operation at the transmitting frequency of the NDB is recommended for this purpose.

6.6.1.4.2 This test, using an oscilloscope, should be made at least every three months. Additionally, rough checks of modulation depth may be made frequently by using a calibrated diodevoltmeter, but these are not a satisfactory substitute for the test using the oscilloscope.

6.6.1.4.3 Unwanted audio frequency modulation should be measured at least every three months to ensure that it does not exceed the limits of Part I, 3.4.6.5. An oscilloscope is also recommended for this test.

6.6.1.5 *Fall of carrier power with modulation*

6.6.1.5.1 When modulation is applied, the carrier power should not decrease by more than the amount specified in Part I, 3.4.6.4. A recommended method of ensuring this is to use, at a suitable remote site, a calibrated communication receiver having a continuous wave IF crystal filter as an indicator of transmitter field strength and having sufficient selectivity to reject the audio sidebands

6.6.1.5.2 An alternative but probably less accurate method of determining the fall of carrier power would be a comparison of the current fed into the antenna when the transmitter is modulated with that when it is not modulated.

6.6.1.5.3 This test should be done at least once a month.

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*

7.1.2.1 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*

7.1.3.1 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*

7.1.4.1 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. Part I, 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 Part I, 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 Part I, 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 In the transition from ILS to MLS, it may be desired 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 7 only permits the coding of DME/P coordinates within certain limits.

7.1.6.6 The nominal location of the zero range indication provided by a DME/N interrogator needs to be published.

7.1.6.7 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 threshold and along the runway. Care should also 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.

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, 7.1.9 and 7.1.10 below. 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. 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

Table C-4. Protection ratio D/U (dB)

Type of assignment:	A	B
Co-frequency:		
Same pulse code	8	8
Different pulse code	0	−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 Part I and providing a decoder rejection conforming to 3.5.5.3.5 of Part I.

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 ERP 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.

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.

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*

7.1.9.1 Assignment of a Y or Z channel whose reply frequency is 63 MHz removed from the reply frequency of another channel (either a W, X, Y or Z channel) or vice versa requires a distance separation of at least 28 km (15 NM) between facilities.

7.1.10 *Special considerations for DME W or Z channel assignments*

7.1.10.1 Assignment of a W or Z channel whose reply frequency is 63 MHz removed from the reply frequency of a Y channel or vice versa requires a distance separation of at least equal to the service volume range of the Y channel facility plus 28 km (15 NM).

7.2 Guidance material concerning DME/N only

7.2.1 *Effective radiated power (ERP) of DME/N facilities*

7.2.1.1 The power density figure prescribed in 3.5.4.1.5.1 of Part I is on the following assumptions:

Airborne receiver sensitivity	– 112 dBW
Airborne transmission line loss	+ 3 dB
Airborne polar pattern loss relative to an isotopic antenna	+ 4 dB
Necessary power at antenna	– 105 dBW

Minus 105 dBW at the antenna corresponds to minus 83 dBW/m² at the mid-band frequency.

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.*

(Reference: *"Antennas" by J.D. Kraus gives aperture figures for other types of antennas.)*

7.2.1.2 Nominal values of the necessary ERP to achieve a power density of minus 83 dBW/m² are given in Figure C-20. For coverage under difficult terrain and siting conditions it may be necessary to make appropriate increases in the ERP. Conversely, under favourable siting conditions, the stated power density may be achieved with a lower ERP.

7.2.1.3 The use of Figure C-20 is illustrated by the following examples. In order to achieve the necessary nominal power density at slant range/levels of 342 km (185 NM)/12 000 m (40 000 ft), 263 km (142 NM)/12 000 m (40 000 ft) and 135 km (73 NM)/6 000 m (20 000 ft), ERPs of the order of plus 42 dBW, plus 36 dBW and plus 30 dBW respectively would be required.

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 Part I, 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 Table A in Part I, Chapter 3. 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*

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. Also the DME/N error at the limits of MLS coverage is consistent with the 0.37 km (0.2 NM) system accuracy in Part I, 3.5.3.1.3.3. 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 PFE corresponds to a plus or minus 1.5 m 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.

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.

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 Part I, 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*

7.3.3.1 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 over-all system performance, as specified in 3.5.3.1.3.4, 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.

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

Table C-5

Function	*Typical distance from the threshold*	*PFE (95% probability)*	*CMN (95% probability)*
Approach (7.3.2.1.2)			
— 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 (7.3.2.1.3)			
— 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
30 m decision height determination (100 ft) (7.3.2.1.4)			
— 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 (7.3.2.1.5)			
— 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 (7.3.2.1.6) (autopilot gain scheduling)	37 km (20 NM) to 0	±250 m (±820 ft)	not applicable
Flare manoeuvre with MLS flare elevation (7.3.2.1.7)			
— CTOL	0	±30 m (±100 ft)	±12 m (±40 ft)
— STOL	0	±12 m (±40 ft)	±12 m (±40 ft)
Long flare alert (7.3.2.1.8)	Runway region	±30 m (±100 ft)	not applicable
CTOL high speed roll-out/turnoffs (7.3.2.1.9)	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 (7.3.2.1.10)	925 m (0.5 NM) to 0	±12 m (±40 ft)	±12 m (±40 ft)
Co-ordinate translations (7.3.2.1.11)	—	±12 m to ±30 m (±40 ft to ±100 ft)	±12 m (±40 ft)

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*

7.3.5.2.1 When track is established, the receiver output consists of valid guidance information before removing the warning. The validation process continues to operate as long

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 3* PFE m (ft)	*IA mode 3* 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.— It should be noted that 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 should 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.

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*

7.3.5.3.1 The accuracy specifications in Part I, 3.5.3.1.3.4, as well as the error budgets discussed in 7.3.3 above, assume that the higher frequency noise contributions are limited by a low pass filter with a corner frequency of ω_2 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*

7.3.5.4.1 The data filter may require a velocity memory in order to achieve the specified accuracies in Part I, 3.5.3.1.3.4 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*

7.3.5.5.1 Range estimates which are significantly different from previous filtered range estimates, because they cannot be the result of aircraft motion, should be assumed 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 Part I, 3.5.4.1.3.4 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 Part I, 3.5.4.5.3 and 3.5.4.5.4. Similarly, the interrogator instrumentation error components, specified in Part I, 3.5.5.4, can be determined.

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/m²	-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

Power budget items	*41 km (22 NM)*	*13 km (7 NM)*	*Ref datum*	*Roll-out*
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

Table C-9. Power supply switch-over times for ground-based radio aids used in the vicinity of aerodromes

Type of runway	*Aids requiring power*	*Maximum switch-over times*
Instrument approach	SRE	15 seconds
	VOR	15 seconds
	NDB	15 seconds
	D/F facility	15 seconds
Precision approach category I	ILS localizer	10 seconds
	ILS glide path	10 seconds
	ILS middle marker	10 seconds
	ILS outer marker	10 seconds
	PAR	10 seconds
Precision approach category II	ILS localizer	0 seconds
	ILS glide path	0 seconds
	ILS inner marker	1 second
	ILS middle marker	1 second
	ILS outer marker	10 seconds
Precision approach category III	(Same as category II)	

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).

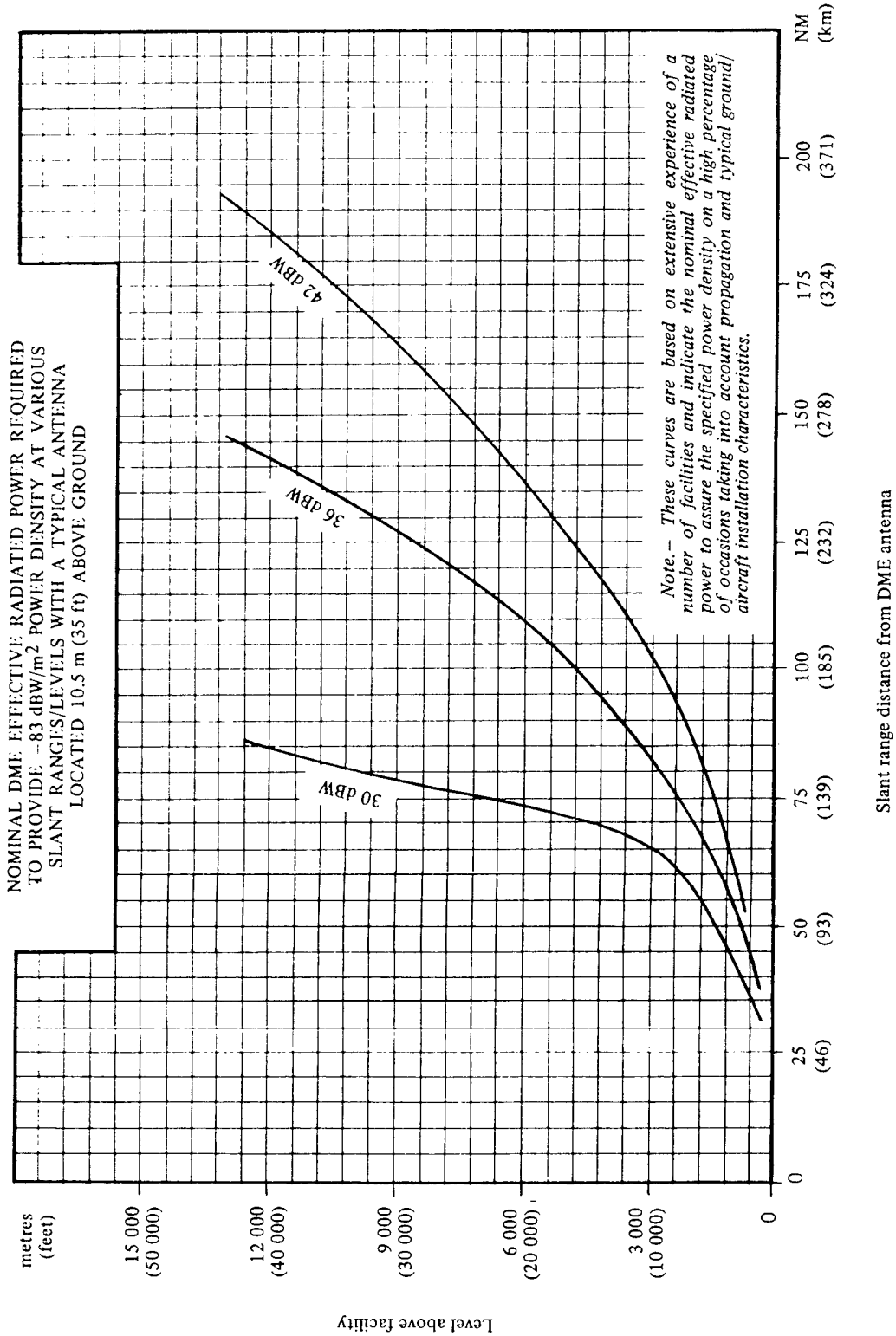
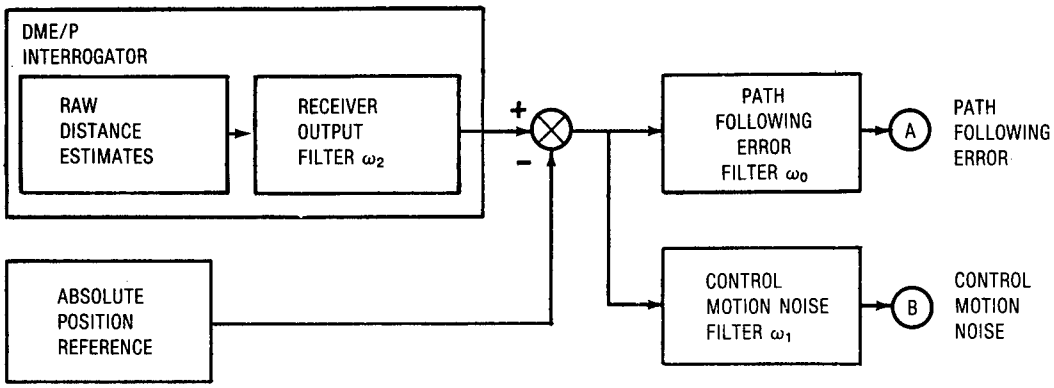

NOMINAL DME EFFECTIVE RADIATED POWER REQUIRED TO PROVIDE −83 dBW/m2 POWER DENSITY AT VARIOUS SLANT RANGES/LEVELS WITH A TYPICAL ANTENNA LOCATED 10.5 m (35 ft) ABOVE GROUND
42 dBW
36 dBW
30 dBW
Note.– These curves are based on extensive experience of a number of facilities and indicate the nominal effective radiated power to assure the specified power density on a high percentage of occasions taking into account propagation and typical ground/aircraft installation characteristics.
Level above facility
metres (feet)
15 000 (50 000)
12 000 (40 000)
9 000 (30 000)
6 000 (20 000)
3 000 (10 000)
0
0
25 (46)
50 (93)
75 (139)
100 (185)
125 (232)
150 (278)
175 (324)
200 (371)
NM (km)
Slant range distance from DME antenna

Figure C-20



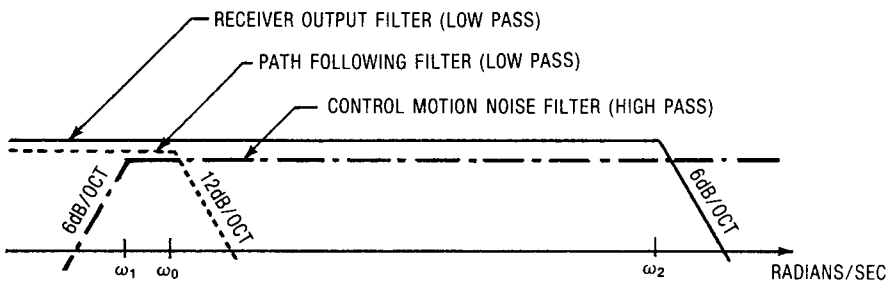
GUIDANCE FUNCTION	CORNER FREQUENCIES (RADIANS/SEC)		
	ω_0	ω_1	ω_2*
DME/P	1.5	0.5	10

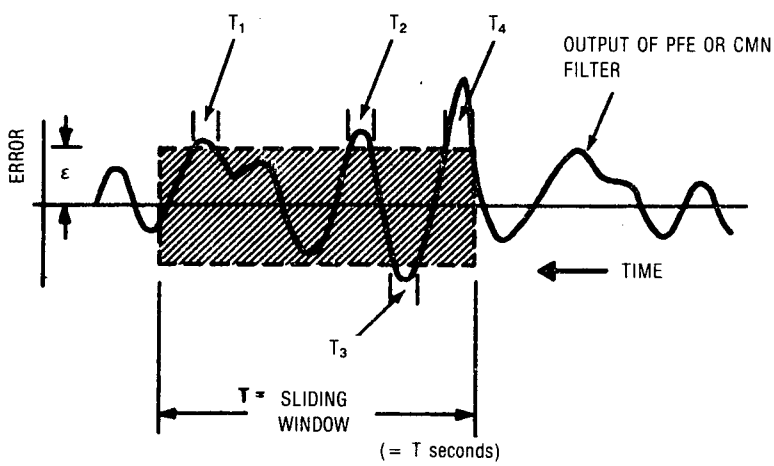
RECEIVER OUTPUT FILTER $\dfrac{\omega_2}{S + \omega_2}$

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: $\dfrac{S}{S + \omega_1}$

* This corner frequency may be less than 10 rad/sec for some applications.





	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

7.3.7.3 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 Part I, 3.5.4.1.3 e).

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*

7.3.9.1 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

8.1.1 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 above indicates representative switch-over times which may be met by power supply systems currently available.

ATTACHMENT D TO PART I. — GUIDANCE MATERIAL FOR COMMUNICATION SYSTEMS

1. Factors affecting radioteletypewriter system engineering

Introductory Note.— This material is intended to provide information and guidance relating to the establishment of radioteletypewriter circuits in accordance with good engineering practice. It is associated with the recommendations for Standards and Recommended Practices in Part I, Chapter 4.

1.1 Signal-to-noise ratio

1.1.1 It is desirable that the received signals should have a minimum signal-to-noise ratio, expressed in RMS values, of not less than 2:1 for one or two channels and not less than 4:1 for three or four channels where time division multiplex is employed. The factors contributing to a satisfactory signal-to-noise ratio are:

a) choice of frequency;

b) selection of receiving site;

c) type of antennas;

d) adequate transmitted power.

1.2 Frequencies

1.2.1 Transmitter and receiver facilities should be provided to cover frequencies necessitated by diurnal, seasonal and solar variations.

1.3 Siting

1.3.1 The receiving station should be located in an area relatively free from local radio and electrical interference so that a signal of reasonable field strength will provide the desired signal-to-noise ratio.

1.4 Antennas

1.4.1 Directional antennas at both the transmitting and receiving stations should be employed wherever the relative positions of the stations on the circuit permit.

1.5 Diversity systems

1.5.1 To improve the average signal strength and to minimize effects of fading, diversity systems should be employed. Of the various systems, space diversity offers the greatest advantages and should be employed wherever possible.

1.6 Signal form

1.6.1 The wave form of radiated pulses (signal form) should not introduce excessive transients and spurious radiations. Perfect rectangular pulses, as may be produced by switching abruptly from the marking to the spacing frequency and vice versa, should be avoided.

2. VHF communications

2.1 Audio characteristics of VHF communication equipment

The aeronautical radiotelephony services represent a special case of the application of radiotelephony, in that the requirement is for the transmission of messages in such a way that fidelity of wave form is of secondary importance, emphasis being upon fidelity of basic intelligence. This means that it is not necessary to transmit those parts of the wave form which are solely concerned with individuality, accent and emphasis.

2.2 Off-set carrier system

The following are examples of off-set carrier systems which meet the requirements of Part I, 4.6.1.1.1:

a) *2-carrier system.* Carriers should be spaced at plus and minus 5 kHz. This requires a frequency stability of plus or minus 2 kHz (15.3 parts per million at 130 MHz).

b) *3-carrier system.* Carriers should be spaced at zero and plus and minus 7.3 kHz. This requires a frequency stability of plus or minus 0.65 kHz (5 parts per million at 130 MHz).

The following are examples or 4- and 5-carrier systems which meet the requirements of Part I, 4.6.1.1.1:

c) *4-carrier system.* Carriers should be spaced at plus and minus 2.5 kHz and plus and minus 7.5 kHz. This requires a frequency stability of plus or minus 0.5 kHz (3.8 parts per million at 130 MHz).

d) *5-carrier system.* Carriers should be spaced at zero, plus and minus 4 kHz and plus and minus 8 kHz. A fre-

quency stability in the order of plus or minus 40 Hz (0.3 parts per million at 130 MHz) is an achievable and practicable interpretation of the requirement in this case.

Note.— The carrier frequency spacings referred to above are with respect to the assigned channel frequency.

2.3 Immunity performance of COM receiving systems in the presence of VHF FM broadcast interference

2.3.1 With reference to the Note of 4.7.3 of Part I, the immunity performance defined there must be measured against an agreed measure of derogation 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 checking of receiving station equipment on bench test can be performed to a repeatable set of conditions, and results, and to facilitate their subsequent approval. An adequate measure of immunity performance may be obtained by the use of wanted signal of minus 87 dBm into the receiving equipment and the signal modulated with a 1 kHz tone at 30 per cent modulation depth. The signal-to-noise ratio should not fall below 6 dB when the interfering signals specified at Part I, 4.7.3.1 and 4.7.3.2 are applied. The broadcast signals should be selected from frequencies in the range between 87.5 and 107.9 MHz and should be modulated with a representative broadcast type signal.

Note 1.— The signal level of minus 87 dBm assumes a combined antenna and feeder gain of 0 dB.

Note 2.— The reduction in the signal-to-noise ratio quoted above is for the purpose of standardization when checking that receiving station equipment on bench measurements meet the required immunity. In the planning of frequencies and in the assessment of protection from FM broadcast interference, a value not less than this, and in many cases higher, depending on the operational circumstances in individual cases, should be chosen as the basis of the interference assessment.

3. SELCAL system

3.1 This material is intended to provide information and guidance relating to the operation of the SELCAL system. It is associated with the Recommended Practices contained in Part I, 4.8.

1) *Function.* The purpose of the SELCAL system is to permit the selective calling of individual aircraft over radiotelephone channels linking the ground station with the aircraft, and is intended to operate on en-route frequencies with existing HF and VHF ground-to-air communications transmitters and receivers with a minimum of electrical and mechanical modification. The normal functioning of the ground-to-air communications link should be unaffected, except at such time as the selective calling function is being formed.

2) *Principles of operation.* Selective calling is accomplished by the coder of the ground transmitter sending a single group of coded tone pulses to the aircraft receiver and decoder. The airborne receiver and decoder equipment is capable of receiving and interpreting, by means of an indicator, the correct code and rejecting all other codes in the presence of random noise and interference. The ground portion of the coding device (ground selective calling unit) supplies coded information to the ground-to-air transmitter. The airborne selective calling unit is the special airborne equipment which operates with existing communications receivers on the aircraft to permit decoding of the ground-to-air signals for display on the signal indicator. The type of signal indicator can be chosen to suit operational requirements of the user and may consist of a lamp, a bell, a chime or any combination of such indicating devices.

4. Independent sideband (ISB) system

4.1 The independent sideband system provides a convenient method of providing, within the same circuit:

a) one or more voice channels; and

b) one or more teletypewriter channels.

4.1.1 The use of the double sideband system for ground-to-ground radiotelephony is rapidly being superseded by the single sideband system which, by suppressing one of the sidebands and reducing the power in the carrier, ensures that the radiated power is more effectively used.

4.1.2 ISB systems may be considered as a logical development of the single sideband system. Beginning from the low level carrier and the single sideband carrying intelligence, it is logical to use the second sideband for the transmission of independent intelligence. For example, one sideband could carry speech and the other could carry teletypewriter channels.

4.1.3 For commercial purposes, ISB systems with two speech channels and the order of 24 teletypewriter channels are common.

4.1.4 An ISB transmission can be provided by any suitable transmitter with a linear output but special modulation equipment is necessary. Two balanced modulators are required, one for each sideband. The carrier frequency itself is removed by filtering and is replaced by a steady pilot carrier at a typical level of 28 dB below the peak sideband power.

4.1.5 Special receivers are necessary. The early stages follow standard design practice adjusted as necessary to provide the necessary bandwidth. Filters separate the pilot carrier and the two sidebands; the first is used to control the receiver gain and thus ensure a controlled output of the intelligence derived by demodulation of the latter.

5. HF radioteletypewriter circuits using four-frequency shift (F7B modulation)

5.1 Multi-channel operation of radioteletypewriter circuits can be provided in the following ways:

a) By *time division* (F1B modulation):

1) by using electronic techniques so that the content of two (or four) modulations at 50 bauds, for example, is transformed by interleaving into a single 100 bauds modulation (or 200 bauds modulation for four channels);

2) by the addition of an Automatic Error Correction (ARQ) system to the circuit.

b) By *frequency division* (F7B modulation) using four frequencies f_1 to f_4 corresponding to the following characteristics:

Coding system

Frequency of emission	*Channel 1*	*Channel 2*
f_4 (highest frequency)	A	A
f_3	A	Z
f_2	Z	A
f_1 (lowest frequency)	Z	Z

Spacing between adjacent frequencies (Hz)	*Nominal modulation rate of each channel (bauds)*
1 000	over 300
500	200 to 300
400	100 to 200
200 or 250	below 100

5.2 With the present state of the technique, where there is a requirement for a maximum of four channels to be operated on a circuit, F1B modulation gives a better spectrum economy than does F7B modulation, for which the necessary bandwidth will always be greater than that required for time-division multiplex operation. For the same reason receivers for F1B would possess a better signal-to-signal noise ratio characteristic. For that reason F1B modulation would be in general preferred to F7B for use on AFTN circuits.

5.3 For circuits having more than four telegraph channels, a combination of frequency division and time division could be used in order to provide, by F7B modulation, two separate "sub-circuits", each one, by time-division giving four channels.

6. Automatic error correction (ARQ) systems

6.1 The requirements for ARQ

The incidence of mutilation on AFTN teletypewriter circuits has been the subject of general concern by aeronautical telecommunication authorities and the conversion of the AFTN to semi-automatic and fully automatic teletypewriter systems operation accentuates the need to prevent mutilation of essential information and the delays caused by the consequent misrouting of messages.

6.1.1 The function of ARQ techniques is to reduce the probability of mutilation of teletypewriter signals by noise or disturbances in the transmission medium, where it is impracticable, or uneconomical, to overcome the adverse effects of these phenomena by other means. Assuming efficient operating personnel and equipment, the largest proportion of errors occurring in messages will result from distortion of the signal form during transit through the transmission medium.

6.1.2 It is evident that any measures taken to improve the performance of a circuit, or to widen the margin of tolerance to noise or distortion of the receiving equipment, will reduce the probability of mutilations and correspondingly, reduce the need for automatic error corrections. Circuit monitoring devices which act so as to permit the movement of message traffic only when an acceptable quality of transmission path prevails, will also reduce the percentage of errors, but less effectively than will ARQ.

6.1.3 To a large extent, therefore, the requirement for automatic error correction on a circuit depends on the percentage of garbled characters occurring after other practicable methods to improve the stability and reliability of the circuit have been applied.

6.2 Advantages and disadvantages of ARQ

Introduction of automatic error correction equipment:

1) will eliminate a large proportion of those errors which at present, for various reasons, are not detected at AFTN stations and thus will result in increasing accuracy and hence in improved service to users;

2) will reduce the proportion of occasions on which a message is misrouted or delayed, by lessening the probability of mutilation of the routing information and/or the end of message signal contained in messages, thereby facilitating the conversion of AFTN relay stations to semi-automatic or fully-automatic operation;

3) will eliminate the message delays and inefficient use of operating personnel, inherent in existing manual methods of obtaining corrections at the time that errors occur;

4) has the disadvantage of costing money. Where the foregoing advantages are the only ones gained, as is the case with wire teletypewriter circuits, Administrations would probably wish to consider more simple and less expensive forms of circuit-monitoring devices suitable for use on wire circuits;

5) makes it possible to use radioteletypewriter circuits for traffic purposes at times when it would otherwise be impracticable because of the incidence of mutilations

during longer or shorter periods. In this respect therefore, the cost of ARQ equipment can frequently be justified a) by the additional circuit availability thus obtained which could otherwise be provided only by the use of additional radioteletypewriter equipment and frequencies, and b) by reduction of the cost of diverting high priority aeronautical traffic to the public (commercial) service channels during prolonged periods of adverse radio conditions which render non-ARQ equipped circuits unusable;

6) obviates the need for manual reprocessing of messages at radioteletypewriter terminals, by enabling these circuits to be directly connected into semi-automatic or fully-automatic relay equipment, with an attendant improvement in message transit-times and a reduction in the number of operating personnel required. This advantage is possible because of the practically error-free operation of ARQ-equipped circuits.

6.3 Available types of ARQ systems

There are at least two entirely different types of ARQ systems in existence:

a) *The 7-unit system.* Synchronous transmissions are made between terminal stations in the International Telegraph Alphabet No. 3 (see Part I, 4.2.2). This alphabet has seven significant elements per character, of which four have polarity "A" and three have polarity "Z". The basic technique in this case is that a complete 7-unit teletypewriter character is accepted only if this ratio is correct.

   If this is not so, the complete character is rejected. A repetition is then requested on the return channel and transmission is repeated until an acceptable character is received.

b) *The 5-unit system.* Synchronous transmissions are made between terminal stations using a 5-unit code. The basic technique in this case is that apart from adding parity elements to the 5-unit code using the two other available units, each signal element is examined over the central portion of its duration in time. Signal elements are accepted only if no transition in polarity during this portion occurs. Teletypewriter signals are rejected in their entirety when either any of the seven signal elements shows a defect or when there is a defect in the parity condition. A repetition is then requested on the return channel and transmission is repeated until the received character is acceptable.

6.4 Relative merits of the 7-unit and the 5-unit systems

6.4.1 Neither of these systems offers complete protection against the acceptance of mutilated characters, because:

a) in the case of the 7-unit system, it is possible, although infrequent, for an interfering signal to produce an undetectable mutilation by changing one element of "Z" polarity into "A" polarity and another from "A" polarity into "Z" polarity within a single 7-unit character, thereby maintaining the 3:4 ratio;

b) in the case of the 5-unit system, it is also possible, although infrequent, for an interfering signal to change two elements into two elements of opposite polarity, without mutilating the shape of any of the seven elements.

6.4.2 It is not possible to state that either of these systems is more resistant to mutilation than the other. This is partly due to the fact that, in the 5-unit system, the criterion of acceptance of a signal element (the "amplitude" and "width" of the "gate") can be varied; the higher the criterion, the lower the mutilation rate at the cost of lower circuit efficiency (in that some signal elements will be rejected unnecessarily and there will be an excess of repetition).

6.4.3 An important factor in the choice between the two systems is that ITU has accepted the 7-unit ARQ principle for international use and standardized the alphabet it should use. It is therefore desirable that first consideration should be given to this 7-unit system when international channels have to be provided with ARQ equipment.

6.4.4 Apart from the above arguments there are a number of other points to be regarded, when considering the introduction of ARQ.

6.4.4.1 The 5-unit ARQ system appears more simple to operate; in particular it will assume synchronism automatically when in service and return to it automatically after an interruption, whereas 7-unit systems require operator intervention.

6.4.4.2 The method by which a repetition is obtained in the 5-unit ARQ system appears to give greater security than does the 7-unit system.

6.4.4.3 Being synchronous systems, the type of signalling is of a "continuous" nature, and distinct from the "start-stop" type of transmission. Therefore, the 7-unit ARQ has been designed for use as a time-division multiplex equipment, which is economically advantageous for cases of circuits with several channels. The 5-unit equipment may be multiplexed either by the use of multiple single units operating on a frequency division basis, or by changing its modulation ratio from 50 to 100 bauds and adding a subdivider so as to provide two time division channels. The 5-unit system therefore offers the most economical ARQ system where a single channel is sufficient for the time being.

6.4.4.4 Both systems appear to need little maintenance effort, as they are both available in a transistorized form. Both employ techniques which, although they may seem new to most radio station personnel, are not in any way more complicated from the point of view of maintenance than other electronic equipment used for aeronautical purposes.

7. Systems of continuous check of channel condition and low speed ITA-2 controlled circuit protocols

7.1 This material is intended to provide information and guidance related to operation of low speed circuits of the AFTN employing International Telegraph Alphabet No. 2 (ITA-2). It is associated with the Recommended Practices contained in Part I, 4.2. Various systems are described in very brief and general terms to assist Administrations in making initial assessments concerning potential application to specific operational requirements. Accordingly, it should be recognized that more detailed functional descriptions should be obtained prior to selection (from a vendor, PTT, or carrier), and analyzed with respect to relative merits, options and application.

7.2 Systems of continuous check of channel condition

7.2.1 The channel check procedure recommended in Volume II, 4.4.11.1.5, is not an optimum method for such parts of the AFTN that operate automatically. It is therefore desirable to introduce a system of continuous check of channel condition. Available systems include those briefly described below.

a) On HF radioteletypewriter circuits, ARQ equipment (described in 6 above) provides circuit continuity by a synchronous error control system and gives alarm in case of severe circuit deterioration.

b) A circuit outage on incoming physical circuits can be detected by a period of 300 milliseconds (or longer) of start polarity (continuous space condition). Similarly, on an incoming circuit including carrier equipment engineered according to CCITT Recommendation R35 (Volume VII), detection of a period of 300 milliseconds or longer of start polarity will signal a circuit outage. In some situations, depending upon the switching centre, a period longer than 300 milliseconds may be applied before alarm to supervisory personnel and/or automatic traffic protection measures are initiated. For example, on the assumption that the associated output is similarly out of service (which may not be the case but is a fail-safe assumption), the automated centre may be programmed to interrupt the output message in progress (if any), cancel the transmission in keeping with the procedure of Volume II, 4.4.13.7, 1) and 2), and discontinue output pending assurance of service restoration. Additionally, on the assumption that the associated output circuit may not be similarly out of service, the automated centre may be programmed to follow the above actions by transmission of an emergency stop signal that will be recognized by the correspondent centre or station equipment and stop its transmission. An example of such an emergency stop signal is alternating 350 milliseconds periods of continuous space and mark condition.

c) A circuit failure on outgoing physical circuits can be detected by a line current guarding relay.

Note.— This does not provide an indication of circuit failure beyond the physical circuit, i.e. in carrier equipment and interconnected physical circuits beyond such carrier equipment.

7.3 Low speed ITA-2 controlled circuit protocols

7.3.1 The application of low speed ITA-2 controlled circuit protocols, as an adjunct to and/or replacement for the continuous check of channel condition systems described in 7.2 above, provides enhanced integrity and reliability to the operation of circuits of the AFTN. When applied to circuits terminated in an automated AFTN centre, it gives the instantaneous capability to (1) control the start and stop of transmissions from its correspondent centres and stations, (2) determine the status of circuit continuity to/from its correspondent centres and stations, and (3) provide for message assurance. Available and typical protocols include those briefly described below.

a) *Full-Duplex ITA-2 Processor-to-Processor Control Protocol.* The purpose of this control protocol is to provide automatic circuit and message assurance and control of a full duplex circuit, interconnecting two message switching processors using asynchronous transmission. The interconnecting circuit serves both for the exchange of message traffic and the control sequences necessary to effect circuit assurance and message control. These sequences, which include a VA sequence to validate the circuit for traffic and an IA sequence to invalidate it, are sent at regular intervals to provide circuit assurance. In addition, an SA control sequence may be invoked by a receiving processor, under momentary overload conditions, to halt temporarily transmission from the connected processor. A detected input line failure or lack of assurance from the other processor will result in the associated output line being placed on automatic hold. Retransmission of all messages which may not have been received will be made by reference to a previously established requeue point, which is continuously maintained and updated by validations from the connected processor.

b) *Half-Duplex ITA-2 Controlled Circuit Protocol.* The purpose of this protocol is to provide an AFTN centre (equipped with a store-and-forward message switching digital processor or auxiliary electromechanical or electronic hardware) positive control of a half-duplex point-to-point or multipoint circuit and its interconnected correspondent AFTN centre or station(s). This control applies to starting or stopping the transmission of input traffic, and the provision prior to delivery of output traffic of an indication from the receiving equipment of the correspondent AFTN centre or station, relative to its operational status. In a point-to-point application, the correspondent AFTN centre can be manually torn-tape operated, or semi- or fully-automated, and may be equipped with electronic data buffer storage units, or with electromechanical buffer units such as reperforator/transmitters, as the transmitting and receiving devices.

The start of input traffic to the controlling AFTN centre is accomplished by transmission of a polling sequence — transmitter start code (TSC) — which invites the interconnected centre, or each station of a multipoint circuit in turn, to transmit. On recognition of its assigned TSC, the polled station responds with either transmission of traffic, or a no-traffic-response signal. The stopping of input traffic may be accomplished by the controlling AFTN centre transmitting an emergency stop signal which immediately stops station transmission, or discontinuing polling, depending on circumstances.

On delivery of output traffic, the controlling AFTN centre transmits a receive select code (RSC) sequence. This RSC is recognized by the selected station. Its equipment is placed in print condition, and a connect-answer-back signal transmitted. This signal is recognized by the controlling AFTN centre which then transmits the message.

Failure of a station to respond to either TSC or RSC results in immediate and automatic traffic protection measures, and appropriate alarms to supervisory personnel.

This protocol gives a continuous indication of circuit continuity and provides message delivery assurance. Consideration of its relative advantages should be based on the application, associated traffic loading, and economics. In a point-to-point application, traffic loading conditions, in conjunction with tariff considerations, may preclude its cost-effective application in that international leased services are costed typically on the basis of full-duplex channels. In a multipoint application, it has the potential advantage of cost-savings compared to individual point-to-point circuits due to the application of distance-related circuit tariffs. Additional savings may be gained in station equipment costs in that a single teletypewriter may be used to accommodate both station-originated and received traffic. Savings may also be realized in equipment, line termination, and/or port requirements in the controlling AFTN centre.

c) *Full-Duplex ITA-2 Processor to Non-Processor Controlled Circuit Protocol.* The purpose of this protocol is to provide an AFTN centre (employing a store-and-forward message switching digital processor) positive control of a full-duplex point-to-point or multipoint circuit and its interconnected correspondent AFTN centre or station(s). This control applies to starting or stopping the transmission of input traffic, and to discontinuing output traffic on recognition of a circuit or station fault condition. In a point-to-point application, the correspondent AFTN centre can be manually torn-tape operated, or semi- or fully-automated, and may be equipped with electronic data buffer storage units, or with electromechanical buffer units such as reperforator/transmitters, as the transmitting and receiving devices.

The start of input traffic to the controlling AFTN centre is accomplished by transmission of a polling sequence — transmitter start code (TSC) — which invites the interconnected centre, or each station of a multipoint circuit in turn, to transmit. On recognition of its assigned TSC, the polled station responds with either transmission of traffic, or a no-traffic-response signal. The stopping of input traffic is accomplished by the controlling AFTN centre transmitting an emergency stop signal or, depending on circumstances, discontinuing polling. Since a polling sequence may necessarily interrupt output traffic in progress, the polling sequence and the interconnected correspondent station equipments are arranged to provide for temporary-print-inhibit (TPI) and return-to-point (RTP) conditions immediately prior to and following the TSC sequence. This arrangement turns the selected receiving equipment on and off to prevent printing of the TSC sequence in an output message that is interrupted for polling.

On delivery of output traffic, the controlling AFTN centre transmits a receive select code (RSC) sequence followed by a pause (continuous mark condition) typically of two to four character lengths' duration. During this pause, the RSC is recognized by the selected station and its equipment is placed in print condition. The message is immediately transmitted from the controlling centre.

Failure of a station to respond to its TSC results in automatic traffic protection measures, and appropriate alarms to supervisory personnel.

This protocol gives a continuous indication of circuit continuity and a degree of message delivery assurance through the polling and associated response arrangements, further supported by message numbering. Consideration of its relative advantages should be based on the application, associated traffic loading, economics and alternatives. In addition to the advantages of positive control of input traffic, circuit assurance, and an improved and reasonable degree of message delivery assurance noted above, it makes full use of the full-duplex capacity of a typical international leased telegraph channel. In a multipoint application, it has the potential advantage of cost-savings over individual point-to-point circuits due to application of distance-related circuit tariffs. Additional savings may also be realized in equipment, line termination and/or port requirements in the controlling AFTN centre.

ATTACHMENT E TO PART I. — GUIDANCE MATERIAL ON THE PRE-FLIGHT CHECKING OF VOR AIRBORNE EQUIPMENT

1. Specification for a VOR airborne equipment test facility (VOT)

1.1 Introduction

For the guidance of States wishing to provide a test signal for the pre-flight checking of VOR airborne equipment, suggested characteristics for a VOR airborne equipment test facility (VOT) are given hereafter.

1.2 General

1.2.1 The VOT must be designed to provide signals that will permit satisfactory operation of a typical VOR aircraft installation in those areas of the aerodrome where pre-flight checking is convenient and desirable.

1.2.2 The VOT must be constructed and adjusted so that the VOR bearing indicator in the aircraft will indicate zero degrees "FROM" when the receiver has not departed from calibration. This indication remains constant irrespective of the aircraft's angular position with respect to the VOT within the intended coverage.

1.2.3 In view of the manner in which use is made of a VOT, there is no fundamental need for its duplication at any one site.

1.2.4 The VOT is required to radiate a radio frequency carrier with which are associated two separate 30 Hz modulations. The characteristics of these modulations shall be identical with the reference phase and variable phase signals associated with VOR. The phases of these modulations shall be independent of azimuth and shall be coincident with each other at all times.

1.3 Radio frequency

The VOT shall operate in the band 108 MHz to 117.975 MHz on an appropriate VOR channel selected so as not to interfere with any VHF navigation or communication services. The highest assignable frequency shall be 117.95 MHz. The frequency tolerance of the radio frequency carrier shall be plus or minus 0.005 per cent, except as specified in Part I, 3.3.2.2 and 3.3.2.3.

1.4 Polarization and accuracy

1.4.1 The emission from the VOT should be horizontally polarized.

1.4.2 The accuracy of the "bearing" information conveyed by the radiation from the VOT shall be plus or minus 1 degree.

Note.— Since the two modulations on the radio frequency carrier are in phase coincidence at all times, the vestigial vertically polarized energy will have no effect on the accuracy of the facility.

1.5 Coverage

1.5.1 Coverage requirements, and hence the power which must be radiated, will necessarily depend to a considerable extent on local circumstances. For some installations, a small fraction of 1 W will suffice while in other cases, particularly if two or more closely adjacent aerodromes are to be served by a single test facility, several watts of radio frequency energy may need to be emitted.

1.5.2 Where there is a need to protect co-channel VORs, VOTs and ILS localizers from VOT interference, the radio emission must be limited to that required to provide satisfactory operation and to ensure that interference with other co-channel assignments does not occur.

1.6 Modulation

1.6.1 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 and having a deviation ratio of 16 plus or minus 1 (i.e. 15 to 17);

b) 30 Hz.

1.6.2 The depth of modulation due to the 9 960 Hz and the 30 Hz signals shall be within the limits of 28 per cent for each component.

1.6.3 The signal which frequency modulates the 9 960 Hz subcarrier and the signal which amplitude modulates the radio frequency carrier shall both be maintained at 30 Hz within plus or minus 1 per cent.

1.6.4 The frequency of the 9 960 Hz subcarrier shall be maintained within plus or minus 1 per cent.

1.6.5 The percentage of amplitude modulation on the 9 960 Hz subcarrier present at the output of the transmitter shall not be greater than 5 per cent.

1.7 Identification

1.7.1 The VOT shall transmit a 1 020 Hz identification signal. The identification code for a VOT installation shall be selected by the competent authority so as to be unmistakably distinctive as to the test function and, if necessary, as to the location.

Note.— In one State, when the VOT coverage is confined to a single aerodrome, the identification consists of a continuous series of dots.

1.7.2 The depth to which the radio frequency carrier is modulated by the identification signal shall be approximately 10 per cent.

1.8 Monitoring

1.8.1 Basically, there is no need for continuous automatic monitoring of VOT provided the relative phase of the AM and FM 30 Hz components are mechanically locked and facilities exist for periodic inspection and remote supervision of the state of the VOT.

1.8.2 Provision of automatic monitoring can double the cost of a VOT installation and, consequently, many competent authorities are likely to employ only remote supervision at a control point. However, where, in the light of the operational use to be made of a VOT, a State decides to provide automatic monitoring, it should possess the following capabilities. The monitor should transmit a warning to a control point and cause a cessation of transmission if either 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 VOT;

b) a reduction of 50 per cent in the signal level of the 9 960 Hz or 30 Hz signals at the monitor.

Failure of the monitor should automatically cause a cessation of transmission.

2. Selection and use of VOR aerodrome check-points

2.1 General

2.1.1 When a VOR is suitably located in relationship to an aerodrome, the pre-flight checking of an aircraft VOR installation can be facilitated by the provision of suitably calibrated and marked check-points at convenient parts of the aerodrome.

2.1.2 In view of the wide variation in circumstances encountered, it is not practicable to establish any standard requirements or practices for the selection of VOR aerodrome check-points. However, States wishing to provide this facility should be guided by the following considerations in selecting the points to be used.

2.2 Siting requirements for check-points

2.2.1 The signal strength of the nearby VOR has to be sufficient to ensure satisfactory operation of a typical aircraft VOR installation. In particular, full flag action (no flag showing) must be ensured.

2.2.2 The check-points should, within the limits of operating convenience, be located away from buildings or other reflecting objects (fixed or moving) which are likely to degrade the accuracy or stability of the VOR signal.

2.2.3 The observed VOR bearing at any selected point should ideally be within plus or minus 1.5 degrees of the bearing accurately determined by survey or chart plotting.

Note.— The figure of plus or minus 1.5 degrees has no direct operational significance in that the observed bearing becomes the published bearing; however, where a larger difference is observed, there is some possibility of poor stability.

2.2.4 The VOR information at a selected point should be used operationally only if found to be consistently within plus or minus 2 degrees of the published bearing. The stability of the VOR information at a selected point should be checked periodically with a calibrated receiver to ensure that the plus or minus 2-degree tolerance is satisfied, irrespective of the orientation of the VOR receiving antenna.

Note.— The tolerance of plus or minus 2 degrees relates to the consistency of the information at the selected point and includes a small tolerance for the accuracy of the calibrated VOR receiver used in checking the point. The 2-degree figure does not relate to any figure for acceptance or rejection of an aircraft VOR installation, this being a matter for determination by Administrations and users in the light of the operation to be performed.

2.2.5 Check-points which can satisfy the foregoing requirements should be selected in consultation with the operators concerned. Provision of check-points in holding bays, at runway ends and in maintenance and loading areas, is usually desirable.

2.3 Marking of VOR check-points

Each VOR check-point must be distinctively marked. This marking must include the VOR bearing which a pilot would observe on his aircraft instrument if his VOR installation were operating correctly.

2.4 Use of VOR check-points

The accuracy with which a pilot must position his aircraft with respect to a check-point will depend on the distance from the VOR station. In cases where the VOR is relatively close to a check-point, particular care must be taken to place the aircraft's VOR receiving antenna directly over the check-point.

ATTACHMENT F TO PART I. — GUIDANCE MATERIAL CONCERNING RELIABILITY AND AVAILABILITY OF RADIOCOMMUNICATIONS AND NAVIGATION AIDS

1. Introduction and fundamental concepts

Due to the rapid increase in numbers of aircraft and the trend towards all-weather operations, aircraft are increasingly dependent upon ground-based navigation and communication facilities. This Attachment is intended to provide guidance material which Member States may find helpful in providing the degree of facility reliability and availability consistent with their operational requirement.

The material in this Attachment is intended for guidance and clarification purposes, and is not to be considered as part of the Standards and Recommended Practices contained in this Annex. It should be noted that this material is tentative, and is still under review.

1.1 Definitions

Facility availability. The ratio of actual operating time to specified operating time.

Facility failure. Any unanticipated occurrence which gives rise to an operationally significant period during which a facility does not provide service within the specified tolerances.

Facility reliability. The probability that the ground installation operates within the specified tolerances.

Note.— This definition refers to the probability that the facility will operate for a specified period of time.

Mean time between failures (MTBF). The actual operating time of a facility divided by the total number of failures of the facility during that period of time.

Note.— The operating time should in general be chosen so as to include at least five, and preferably more, facility failures in order to give a reasonable measure of confidence in the figure derived.

Signal reliability. The probability that a signal-in-space of specified characteristics is available to the aircraft.

Note.— This definition refers to the probability that the signal is present for a specified period of time.

1.2 Facility reliability

1.2.1 Reliability is achieved by a combination of factors. These factors are variable and may be individually adjusted for an integrated approach that is optimum for, and consistent with, the needs and conditions of a particular environment. For example, one may compensate to some extent for low reliability by providing increased maintenance staffing and/or equipment redundancy. Similarly, low levels of skill among maintenance personnel may be offset by providing equipment of high reliability.

1.2.2 The following formula expresses facility reliability as a percentage:

$$R = 100\, e^{-t/m}$$

where R = reliability (probability that the facility will be operative within the specified tolerances for a time t, also referred to as probability of survival, P_s.);

e = base of natural logarithms;

t = time period of interest;

m = mean time between facility failures.

It may be seen that reliability increases as mean time between failures (MTBF) increases. For a high degree of reliability, and for operationally significant values of t, we must have a large MTBF; thus, MTBF is another more convenient way of expressing reliability.

1.2.3 Experimental evidence indicates that the above formula is true for the majority of electronic equipments where the failures follow a Poisson distribution. It will not be applicable during the early life of an equipment when there is a relatively large number of premature failures of individual components; neither will it be true when the equipment is nearing the end of its useful life.

1.2.4 At many facility types utilizing conventional equipment, MTBF values of 1 000 hours or more have been consistently achieved. To indicate the significance of a 1 000-hour MTBF, the corresponding 24-hour reliability is approximately 97.5 per cent (i.e. the likelihood of facility failure during a 24-hour period is about 2.5 per cent).

1.2.5 Figure F-1 shows the probability of facility survival, P_s, after a time period, t, for various values of MTBF.

Note.— It is significant that the probability of surviving a period of time equal to the MTBF is only 0.37 (37 per cent); thus, one should not succumb to the temptation to assume that the MTBF is a failure-free period.

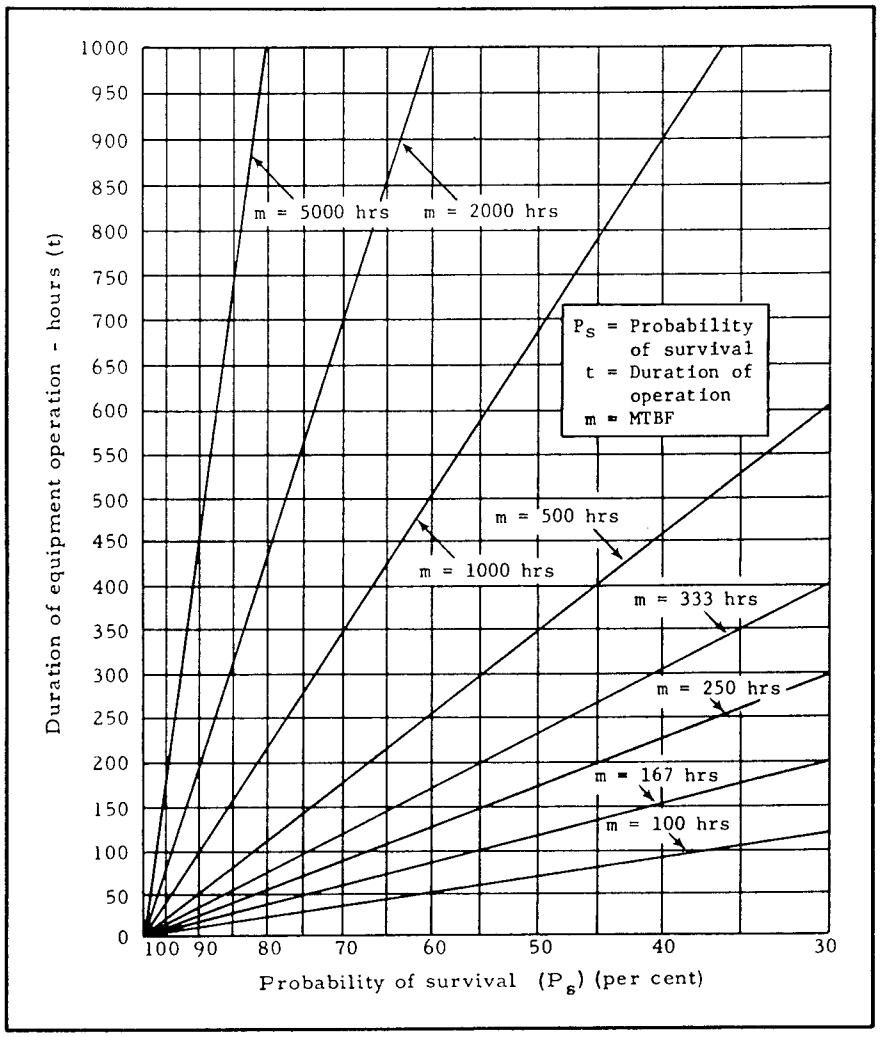


Figure F-1. Plot of $P_s = 100\ e^{-t/m}$

1.2.6 It may be seen that adjustment of MTBF will produce the desired degree of reliability. Factors which affect MTBF and hence facility reliability are:

a) inherent equipment reliability;

b) degree and type of redundancy;

c) reliability of the serving utilities such as power and telephone or control lines;

d) degree and quality of maintenance;

e) environmental factors such as temperature and humidity.

1.3 Facility availability

1.3.1 Availability, as a percentage, may be expressed in terms of the ratio of actual operating time divided by specified operating time taken over a long period.

Symbolically,

$$A = \frac{\text{Actual operating time (100)}}{\text{Specified operating time}}$$

For example, if a facility was operating normally for a total of 700 hours during a 720 hour month, the availability for that month would be 97.2 per cent.

1.3.2 Factors important in providing a high degree of facility availability are:

a) facility reliability;

b) quick response of maintenance personnel to failures;

c) adequate training of maintenance personnel;

d) equipment designs providing good component accessibility and maintainability;

e) efficient logistic support;

f) provision of adequate test equipment;

g) standby equipment and/or utilities.

2. Practical aspects of reliability and availability

2.1 Measurement of reliability and availability

2.1.1 *Reliability.* The value that is obtained for MTBF in practice must of necessity be an estimate since the measurement will have to be made over a finite period of time. Measurement of MTBF over finite periods of time will enable Administrations to determine variations in the reliability of their facilities.

2.1.2 *Availability.* This is also important in that it provides an indication of the degree to which a facility (or group of facilities) is available to the users. Availability is directly related to the efficiency achieved in restoring facilities to normal service.

2.1.3 The basic quantities and manner of their measurement are indicated in Figure F-2. This figure is not intended to represent a typical situation which would normally involve a larger number of inoperative periods during the specified operating time. It should also be recognized that to obtain the most meaningful values for reliability and availability the specified operating time over which measurements are made should be as long as practicable.

2.1.4 Using the quantities illustrated in Figure F-2, which includes one scheduled shutdown period and five failure periods, one may calculate mean time between failures (MTBF) and availability (A) as follows:

Let:

$$a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 = 5\,540 \text{ hours}$$
$$s_1 = 20 \text{ hours}$$
$$f_1 = 2\tfrac{1}{2} \text{ hours}$$
$$f_2 = 6\tfrac{1}{4} \text{ hours}$$
$$f_3 = 3\tfrac{3}{4} \text{ hours}$$
$$f_4 = 5 \text{ hours}$$
$$f_5 = 2\tfrac{1}{2} \text{ hours}$$
$$\text{Specified operating time} = 5\,580 \text{ hours}$$

$$\text{MTBF} = \frac{\text{Actual operating time}}{\text{Number of failures}}$$

$$= \frac{\sum_{i=1}^{7} a_i}{5}$$

$$= \frac{5\,540}{5} = 1\,108 \text{ hours}$$

$$A = \frac{\text{Actual operating time} \times 100}{\text{Specified operating time}}$$

$$= \frac{\sum_{i=1}^{7} a_i \times 100}{\sum_{i=1}^{7} a_i + s_1 + \sum_{i=1}^{5} f_i}$$

$$= \frac{5\,540}{5\,580} \times 100 = 99.3 \text{ per cent.}$$

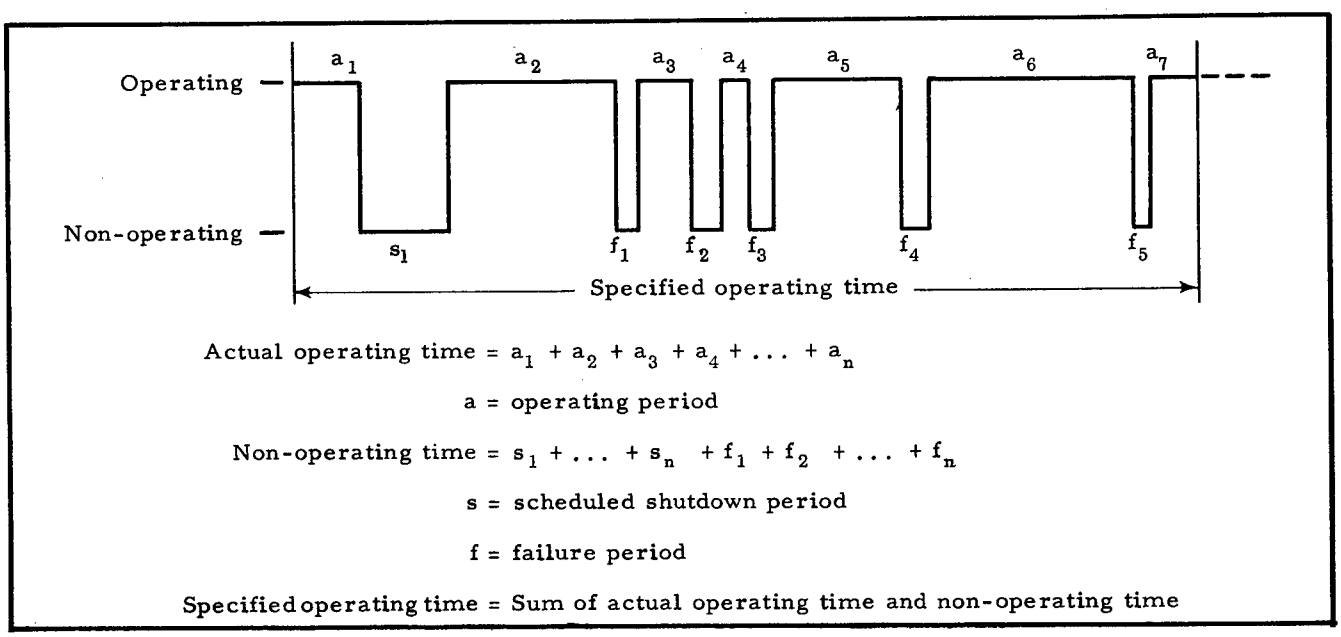


Figure F-2. Evaluation of facility availability and reliability

ATTACHMENT G TO PART I. — INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE MLS STANDARDS AND RECOMMENDED PRACTICES IN ANNEX 10

1. Definitions

Dynamic side-lobe level. The level that is exceeded 3 per cent of the time by the scanning antenna far field radiation pattern exclusive of the main beam as measured at the function scan rate using a 26 kHz beam envelope video filter. The 3 per cent level is determined by the ratio of the side-lobe duration which exceeds the specified level to the total scan duration.

Effective side-lobe level. That level of scanning beam side-lobe which in a specified multipath environment results in a particular guidance angle error.

Standard receiver. The airborne receiver model assumed in partitioning the MLS error budgets. The salient characteristics are: (1) signal processing based on the measurement of beam centres; (2) negligible centring error; (3) control motion noise (CMN) less than or equal to the values contained in Part I, 3.11.6.1.1.2; (4) a 26 kHz bandwidth 2-pole low pass beam envelope filter; and (5) angle data output filtering by a single pole, low pass filter with a corner frequency of 10 radians per second.

2. Signal-in-space characteristics — angle functions

2.1 Signal format organization

2.1.1 The signal format is based on time-division multiplexing wherein each angle guidance function is transmitted in sequence and all are transmitted on the same radio frequency. The angle information is derived by measuring the time difference between the successive passes of highly directive, unmodulated fan beams. Functions may be transmitted in any order. Recommended time slots are provided for the approach azimuth, approach elevation, flare, and back azimuth angle functions. The format includes additional time for growth of future functions such as 360-degree azimuth. Preceding each scanning beam and data transmission is a preamble which is radiated throughout the coverage volume by a sector antenna. The preamble identifies the next scan function and also synchronizes the airborne receiver signal processing circuits and logic.

2.1.2 In addition to the angle scan function, there are basic and auxiliary data functions, each with its own preamble, which are also transmitted from the sector antennas. The preamble permits each function to be recognized and processed independently. Consequently, functions can be added to or deleted from the ground configurations without affecting the operation of the receiver. The codes used in the preamble and data functions are modulated by differential phase shift keying (DPSK).

2.1.3 Examples of the angle function organization and timing are shown in Figures G-1 and G-2. Details and definitions of the data items shown in Figure G-1 are given in Part I, 3.11.4.8.

2.1.4 The sequences of angle guidance and data transmissions shown in Figures G-3A, G-3B and G-3C have been demonstrated to provide freedom from synchronous interference.

2.1.4.1 These sequences are intended to provide sufficient randomization to preclude synchronous interference such as may be caused by propeller rotation effects.

2.1.4.2 The sequence pair shown in Figure G-3A accommodates the transmission of all functions. Any function not required may be deleted so long as the remaining functions are transmitted in the designated time positions.

2.1.4.3 The sequence pair shown in Figure G-3B accommodates the high rate approach azimuth function. Any function not required may be deleted so long as the remaining functions are transmitted in the designated time positions.

2.1.4.4 Figure G-3C shows the complete time multiplex transmission cycle which may be composed of the sequence pairs from Figure G-3A or from Figure G-3B. The open time periods between sequences can be used for the transmission of auxiliary data words as indicated. Basic data words also may be transmitted in any open time period.

2.2 Angle guidance parameters

2.2.1 The angle guidance parameters that define the MLS angle measurement process are specified in Part I, 3.11.4.5. Two additional parameters that are useful in visualizing the operation of the system are the midscan time (T_m) and the pause time. They may be derived from the Part I specifications, and are shown for reference in the following table.

Signal format midscan and pause times
(see Figure G-2)

Function	*Midscan* time, T_m (μs)*	*Pause time (μs)*
Approach azimuth	7 972	600
High rate approach azimuth	5 972	600
Back azimuth	5 972	600
Approach elevation	2 518	400
Flare elevation	2 368	800

* Measured from the receiver reference time (Part I, Table A)

2.2.2 *Function timing accuracy.* Because of the inaccuracy in the determination of the reference time of the Barker code, and because the transmitter circuits smooth the phase or amplitude during phase transitions of the DPSK modulation, it is not possible to determine the timing of the signal with an accuracy better than 2 microseconds from the signal-in-space. It is therefore necessary to measure the timing accuracy specified in Part I, 3.11.4.3.4 on the ground equipment. Suitable test points should be provided in the ground equipment.

2.3 Azimuth guidance functions

2.3.1 *Scanning conventions.* Figure G-4 shows the approach azimuth and back azimuth scanning conventions.

2.3.2 *Coverage requirements.* Figures G-5 and G-6 illustrate the azimuth coverage requirements specified in Part I, 3.11.5.2.2.

2.3.2.1 When the approach or back azimuth antenna sites are necessarily offset from the runway centre line, the following factors should be considered:

a) coverage requirements throughout the runway region;

b) accuracy requirements at the applicable reference datum;

c) approach azimuth to back azimuth transition; and

d) potential disturbances due to moving vehicles, aircraft or airport structures.

2.3.2.2 It is expected that an offset azimuth antenna normally will be adjusted such that the zero degree course line is either parallel to the runway centre line or passes through the applicable reference datum.

2.3.3 *High rate approach azimuth.* Where the approach proportional guidance sector is plus or minus 40 degrees or less and the flare elevation function or other growth functions are not used, it is possible to use a higher scanning rate for the azimuth function. The high rate approach azimuth function is available to offset the increase in CMN caused by large beamwidth antennas (e.g. 3 degrees). Reducing the CMN provides two benefits: 1) angle guidance signal-in-space power density requirements can be reduced; and 2) dynamic side-lobe level requirements can be relaxed.

2.3.3.1 In general, this function will reduce the CMN caused by wide bandwidth, uncorrelated sources such as diffuse multipath or receiver thermal noise by a factor of $\sqrt{1/3}$ relative to the basic 13 Hz function rate. However, the full reduction of power density by $\sqrt{1/3}$ cannot be realized for all ground antenna beamwidths because of the requirement to provide sufficient power density for signal acquisition on a single scan basis. Figure G-12 shows that power requirements can be reduced by a factor of $\sqrt{1/3}$ (= 4.8 dB) by using the higher data rate for 3-degree beamwidth antennas, 2.8 dB for 2-degree beamwidth antennas, and no reduction occurs for the 1-degree beamwidth antenna.

It should be noted that the power required for DPSK transmissions may be such that no economies are realized in the ground equipment transmitters by using the higher data rate (see Table G-1).

2.3.3.2 However, with respect to the CMN performance, the full benefit of the increased data rate can be realized. For example, at the minimum signal levels shown in Table G-2, the azimuth CMN can be reduced from 0.12 degree to 0.07 degree for the 1-degree beamwidth and from 0.2 degree to 0.12 degree for the 2-degree and 3-degree beamwidth antennas. Thus, the application of high rate azimuth is most beneficial to wider beamwidth antennas.

2.3.4 *Clearance*

2.3.4.1 Where used, clearance pulses are transmitted adjacent to the scanning beam signals at the edges of proportional coverage as shown in the timing diagram in Figure G-14. The proportional coverage boundary is established at one beamwidth inside the scan start/stop angles, such that the transition between scanning beam and clearance signals occurs outside the proportional coverage sector. Examples of composite waveforms which may occur during transition are shown in Figure G-16.

2.3.4.2 When clearance guidance is provided in conjunction with a narrow beamwidth (e.g. one degree) scanning antenna, the scanning beam antenna should radiate for 15 microseconds while stationary at the scan start/stop angles.

2.3.4.3 At some locations it may be difficult to satisfy the amplitude criteria of Part I, 3.11.6.2.5.2, because of clearance signal reflections. At these locations the scan sector may be extended.

2.3.4.4 Care should be taken with respect to the fly-right/fly-left clearance convention change when approaching azimuth stations in an opposite direction (e.g. approach towards the back azimuth antenna).

2.3.5 *Approach azimuth monitoring.* The intention of monitoring is to guarantee the guidance integrity appropriate for the promulgated approach procedure. It is not intended that all azimuth radials be monitored independently, but that at least one approach radial, normally the extended runway centre line, be monitored and that adequate means be provided to ensure that the performance and integrity of the other radials are maintained.

2.3.6 *Lower coverage limit determination.* When the threshold is not in line of sight of the approach azimuth antenna, the height of the lower limit of the approach azimuth coverage in the runway region should be determined by finding the lowest point above the runway centre line at the threshold which is in line of sight of the azimuth antenna. This point can be determined on the field or computed as in the example of Figure G-15. The lower limit of the azimuth coverage, to be published, is the height of this point over the threshold plus 2.5 m (8 ft).

2.4 Elevation guidance functions

2.4.1 *Scanning conventions.* Figure G-7 shows the approach elevation and flare scanning conventions.

2.4.2 *Coverage requirements.* Figures G-8 and G-9 illustrate the elevation requirements specified in Part I, 3.11.5.3.2.

2.4.3 *Elevation monitoring.* The intention of monitoring is to guarantee the guidance integrity appropriate for the promulgated approach procedure. It is not intended that all glide paths be monitored independently, but that at least one, normally the minimum glide path, be monitored, and that adequate means be provided to ensure that the performance and integrity of the other glide paths are maintained.

2.5 Accuracy

2.5.1 *General*

2.5.1.1 System accuracy is specified in Part I, in terms of the path following error (PFE), path following noise (PFN), and control motion noise (CMN). These parameters are intended to describe the interaction of the angle guidance signal with the aircraft in terms which can be directly related to aircraft guidance errors and the flight control system design.

2.5.1.2 The system PFE is the difference between the airborne receiver angle measurement and the true position angle of the aircraft. The guidance signal is distorted by ground and airborne equipment errors and errors due to propagation effects. To assess the suitability of the signal-in-space for aircraft guidance, these errors are viewed in the pertinent frequency region. The PFE includes the mean course error and the PFN.

2.5.2 *MLS measurement methodology*

2.5.2.1 The PFE, PFN, and CMN are evaluated by using the filters defined in Figure G-10. The filter characteristics are based on a wide range of existing aircraft response properties, and are considered adequate for foreseeable aircraft designs as well.

2.5.2.2 While the term "PFE" suggests the difference between a desired flight path and the actual flight path taken by an aircraft following the guidance signal, in practice, this error is evaluated by instructing the flight inspection pilot to fly a desired MLS course and recording the difference between the airborne equipment output guidance indication from the PFE filter and the corresponding aircraft position measurement as determined by a suitable position reference. A similar technique using the appropriate filter determines the CMN.

2.5.2.3 *Error evaluation.* The PFE estimates are obtained at the output of the PFE filter (test point A in Figure G-10). The CMN estimates are obtained at the output of the CMN filter (test point B in Figure G-10). Filter corner frequencies are shown in Figure G-10.

2.5.2.3.1 The PFE and CMN for approach azimuth or for back azimuth are evaluated over any 40-second interval of the flight error record taken within the coverage limits (i.e. T = 40 in Figure G-11). The PFE and CMN for approach elevation or for flare elevation are evaluated over any 10-second interval of the flight error record taken within the coverage limits (i.e. T = 10 in Figure G-11).

2.5.2.3.2 The 95 per cent probability requirement is interpreted to be met if the PFE or CMN does not exceed the specified error limits for more than 5 per cent of the evaluation interval (see Figure G-11).

2.5.2.3.3 An alternative flight inspection procedure can be used which does not rely on an absolute reference. In this procedure, only the fluctuating components of the flight record produced at the output of the PFE filter are measured and compared with the PFN standard. The average value of the PFE is assumed to not exceed the mean course alignment specified during the flight inspection period. Therefore, the mean course alignment is added to the PFN measurement for comparison with the specified system PFE. The CMN may be similarly evaluated without accounting for the mean course alignment.

2.5.2.4 *Ground and airborne instrumentation errors.* The instrumentation error induced by the ground and airborne equipment may be determined by measurements taken in an environment which is free from reflected signals or other propagation anomalies which can cause beam envelope perturbations.

2.5.2.4.1 First, the instrumentation errors associated with the standard airborne receiver are determined using a bench test instrument, and the centring error is adjusted to zero. Airborne equipment errors can be measured by recording 40 seconds of data using a standard bench test set. The data can then be divided into four 10-second intervals. The average of each interval is considered to be the PFE while twice the square root of its associated variance is the CMN.

Note.— The receiver output may be evaluated using the PFE and CMN filters, if desired.

2.5.2.4.2 Second, this standard receiver is used to measure the total system instrumentation error by operating the ground equipment on an antenna range or in some other reflection-free environment. Since the receiver centring error has been made negligible, the measured PFE can be attributed to the ground equipment. The ground equipment CMN is obtained by subtracting the known standard receiver CMN variance from the CMN variance of the measurement. The average error over a 10-second measurement interval is considered to be the PFE, while twice the square root of the differential variances is considered to be the instrumental CMN.

2.6. Power density

2.6.1 *General*

2.6.1.1 Three criteria establish the angle power budgets:

a) angle single-scan acquisition requires a 14-dB signal-to-noise ratio (SNR) as measured at the beam envelope filter (i.e. the video SNR);

b) the angle CMN must be maintained within specified limits;

c) the DPSK transmissions must have a detection probability at the extremes of coverage of at least 72 per cent.

2.6.1.2 The source of CMN at 37 km (20 NM) is primarily internal receiver thermal noise. The noise induced error ($d\theta$) can be estimated by:

$$d\theta = \frac{\theta_{BW}}{2(\sqrt{SNR}\sqrt{g})} \qquad \text{(95\% probability)}$$

$$g = \frac{\text{Function sample rate}}{2\ \text{(Filter noise bandwidth)}}$$

where θ_{BW} is the antenna beamwidth in degrees and g is the ratio of the function sample rate to the noise bandwidth of the receiver output filter. This expression reflects the CMN dependence upon ground antenna beamwidth and sample rate.

2.6.2 *System power budget*

2.6.2.1 The system power budget is presented in Table G-1. The power density specified in Part I, 3.11.4.10.1, is related to the signal power specified in Table G-1 at the aircraft antenna by the relation:

Power into isotropic antenna (dBm) =
Power density (dBW/m²) - 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 above 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 Figure G-12 interpolates the minimum power density required for ground antenna beamwidths other than those specified in Part I, 3.11.4.10.1.

2.6.2.6 To support autoland operations, power densities higher than those specified for the approach azimuth angle signals in 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 *Airborne power budget*

2.6.3.1 Table G-2 provides an example of an airborne power budget used in developing the power density standards.

2.7 *DPSK data signal characteristics.* The DPSK data is transmitted by differential phase modulation of the radio frequency carrier with relative phase states of 0 or 180 degrees. The data signal has the following characteristics:

date rate	— 15.625 kHz
bit length	— 64 microseconds
logic "0"	— no phase transition
logic "1"	— phase transition

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 glide path angle, as detected by a standard receiver, should conform to the limits specified in Figure G-13 under conditions of high SNR and negligible multipath (e.g. during a trial on an antenna range).

3.2 Scanning beam side-lobes

3.2.1 *Performance specification.* The antenna side-lobe design should satisfy two conditions: 1) the dynamic side-lobe level should 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 minus 10 dB; 2) the effective side-lobe level should be 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 $d\theta$ 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.

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 and flare antenna should gradually de-emphasize the signal away from the antenna boresight. Typically the horizontal pattern of the approach elevation antenna should be reduced by 3 dB at 20 degrees off the boresight and by 6 dB at 40 degrees. Also typically the horizontal pattern of the flare antenna should be reduced to as low as practicable beyond 10 degrees off the boresight and by at least 12 dB at 40 degrees off the boresight. Depending on the actual multipath conditions, the horizontal radiation pattern may require more or less de-emphasis.

4. MLS/ILS collocation

4.1 *MLS elevation antenna.* Siting of the MLS elevation facility will be affected by the presence or absence of an ILS glide path facility. When collocating MLS with an existing ILS glide path, the threshold crossing height of the minimum MLS glide path should be equal to the commissioned ILS glide path providing the latter is within Annex 10 tolerances. Since the phase centre height of the MLS elevation antenna may be 2.74 m (9 ft) (flat terrain assumed), the MLS antenna must then be positioned forward of the ILS antenna. The position inboard to the ILS antenna (nearer to runway centre line) is also preferred. For example, a 3-degree glide path will place a 2.74 m (9 ft) phase centre height MLS antenna 52 m (172 ft) in front of the ILS antenna.

5. Operational consideration 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 described 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.

a) *Approach azimuth failure.* Control action should permit back azimuth, data and distance measuring functions to radiate.

b) *Approach elevation failure.* Control action should permit other angle, data and distance measuring functions to radiate.

c) *Flare elevation failure.* Control action should permit other angle, data and distance measuring functions to radiate.

d) *Back azimuth failure.* Control action should permit other angle, data and distance measuring functions to radiate.

e) *Basic data word failure.* Control action should permit other angle, data and distance measuring functions to radiate.

f) *Auxiliary data word failure.* Control action should permit other angle, data and distance measuring functions to radiate.

g) *DME failure.* Control action should permit other angle and data functions to radiate.

Note 1.— Basic data and auxiliary data monitors should have the ability to detect the failure of an individual data word and remove that word from the data transmission, while permitting radiation of the remaining data.

Note 2.— This information is presented in graphic form in Table G-3.

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 Part I, 3.11 and include allowances, where appropriate, for:

a) variation of the ground equipment parameters within the limits defined in Part I, 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 interconnexions.

Note 2.— Detailed "Minimum Performance Specifications" for MLS avionics have been compiled and co-ordinated by the European Organization for Civil Aviation Electronics (EUROCAE), and the Radio Technical Commission for Aeronautics (RTCA). ICAO periodically provides to Contracting States current lists of the publications of these organizations co-ordinated internationally in accordance with Recommendations 3/18(a) and 6/7(a) of the Seventh Air Navigation Conference.

7.1.2 The airborne equipment should be capable of decoding the approach azimuth, high rate approach azimuth, back azimuth, and approach elevation functions, and basic data essential to these functions. Range information should be decoded independently.

7.1.3 The receiver should decode 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 Part I, 3.11.4.5.

7.1.4 The receiver should be capable of normal processing of each radiated function without regard to the position of the function in the transmitted sequences.

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 Part I, 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 Part I, 3.11.6, should be met when, in addition, interference on the same channel is received at a level not exceeding that specified in Part I, 3.11.4.1.4.

7.3 Signal processing

7.3.1 *Acquisition*

7.3.1.1 The receiver should, in the presence of a valid input signal, acquire and validate the signal before transitioning to the track mode within two seconds. After loss of the acquired signal, the receiver should provide a warning output within one second during which time the guidance information should remain at the last valid value.

7.3.2 *Track*

7.3.2.1 While tracking, the receiver provides protection against short duration 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.

Note.— Signal validation requires that the receiver repeatedly confirm that the signal being acquired or tracked is the largest and most persistent signal within the coverage.

7.3.3 *Multipath performance*

7.3.3.1 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.

7.3.3.1.1 *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).

7.3.3.1.2 *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.

7.3.4 *Clearance*

7.3.4.1 The airborne equipment should provide clearance guidance information whenever the antenna is in the presence of a valid clearance guidance signal.

7.3.4.2 When the decoded angle indication is outside the proportional guidance sector defined in Part I, Table A-7, the MLS guidance signal should be interpreted as clearance guidance.

7.3.4.3 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-16. The receiver shall also be required to process rapid changes of indicated angle of the order of 1.5 degrees (peak amplitude) when outside the proportional guidance limits.

7.3.4.4 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.

7.3.5 *Basic data*

7.3.5.1 The receiver should decode the following basic data defined in Part I, 3.11.4.8.2.1:

a) approach azimuth to threshold distance;

b) approach azimuth proportional coverage limit;

c) back azimuth antenna distance;

d) back azimuth proportional coverage limit;

e) minimum glide path; and

f) clearance signal type.

If the receiver does not decode basic data essential to the transmitted function, a suitable warning should be provided.

7.4 Control and output

7.4.1 *Deviation scale factor*

7.4.1.1 When the deviation information is intended to have the same sensitivity characteristics as ILS, the deviation scale factor should be determined as follows.

7.4.1.1.1 *Azimuth.* The deviation information should be a function of the "approach azimuth to threshold distance", as supplied by the basic data, such that it is nominally equivalent to ILS at the landing threshold.

7.4.1.1.2 *Back azimuth.* The deviation information should be a function of the "back azimuth antenna distance" so as to provide a smooth transition from approach azimuth to back azimuth guidance.

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, should 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.

8. Operations outside the promulgated MLS coverage sectors

8.1 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 three techniques to further reduce the probability of encountering erratic flag activity.

8.1.1 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.

8.1.2 The approach azimuth sector guidance alert data provide the elevation angles below which azimuth guidance signals in a specific sector should not be used. This information is especially useful in conditions where the direct signal

is blocked, and the signal at the receiver is caused by a reflection into the shadow region. This information is transmitted in Basic Data Word 3.

8.1.3 OCI 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 OCI signal into the region which is greater in magnitude than the undesired guidance signal.

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 below as desired to undesired (D/U) signal ratios and when combined with appropriate propagation losses allow evaluation of MLS C-Band frequency assignments as regards on-channel and adjacent channel interference. When selecting frequencies for MLS facilities, a similar criteria for the DME/P element or an associated DME/N as provided in Attachment C to this Part need to be considered.

9.2 Co-frequency requirements

9.2.1 Co-frequency MLS channel assignments require a D/U equal to or greater than plus 25 dB for the azimuth scanning beams of the desired and undesired facilities. This D/U value will provide frequency protection for MLS angle configurations which produce received power differentials between the desired azimuth scanning beam and DPSK functions up to 20 dB.

9.3 Adjacent frequency requirements

9.3.1 The first and second MLS C-Band adjacent frequencies require a D/U ratio equal to or greater than minus 20.5 dB and minus 25 dB respectively. These D/U values are for the DPSK functions of the desired and undesired signals. Concerning the required frequency protection, the third adjacent frequency need not be protected. As the maximum undesired signal that can be coupled to the angle receiver operating at the worst case point in the MLS service volume is 23.5 dB, only the first and possibly the second adjacent frequencies require assignment protection.

9.3.2 Because of the small existing differentials, if either the off-frequency rejection ratio used (32.5 dB) or the coupled D/U values are other than indicated, adjusted values must be used to determine if the second adjacent frequency needs to be protected.

Table G-1. System power budget
(±40°azimuth coverage; 0-20° vertical coverage; 20 NM range)

			Angle beamwidth		
			Azimuth		Elevation
Power budget items[1]	AZ DPSK	Clearance	2°	3°	2°
Signal required at aircraft (dBm)	-95	-93.5	-91	-87.5	-93.5
Propagation loss[2] (dB)	138.7	138.7	138.7	138.7	138.1
Probabilistic losses (dB):					
a) Polarization	0.5	0.5	0.5	0.5	0.5
b) Rain	2.2	2.2	2.2	2.2	2.2
c) Atmospheric	0.3	0.3	0.3	0.3	0.3
d) Horizontal multipath	3.0	3.0	0.5	0.5	—
e) Vertical multipath	2.0	2.0	2.0	2.0	1.0
Total a) through e) route sum square (RSS) (dB)	4.3	4.3	3.1	3.1	2.5
Horizontal and vertical pattern loss (dB)	—	1.0	2.0	2.0	6.0
Monitor loss (dB)	1.5	1.5	1.5	1.5	1.5
Antenna gain[3] (dB)	—	-13.3	-16.3	-14.4	-14.1
Net power gain at coverage extremes (dB)	-7.3	—	—	—	—
Required transmitter power (dBm)	42.1	38.6	38.0	43.4[4]	40.5

(1) Losses and antenna gains are representative values.
(2) Distance to azimuth antenna taken as 41.7 km (22.5 nautical miles).
(3) The required transmitter power can be reduced by using higher efficiency antennas.
(4) High data rate for 3° azimuth beamwidth will reduce required transmitter power by 4.8 dB.

Table G-2. Airborne power budget

Power budget item	DPSK	Clearance	Azimuth beamwidth				Elevation beamwidth	
			1°	2°	3°	3°(1)	1°	2°
If SNR required for:								
a) 72% decode rate (dB)	5	–	–	–	–	–	–	–
b) 0.2° CMN (dB)	–	–	–	9	12.5	7.7	–	–
c) Acquisition (dB)	–	6.5	6.5	–	–	–	6.5	6.5
Noise figure (dB)	11	11	11	11	11	11	11	11
Noise power in 150 kHz IF bandwidth (dBm)	-122	-122	-122	-122	-122	-122	-122	-122
Cable loss (dB)	5	5	5	5	5	5	5	5
Airborne antenna gain (dBi)	0	0	0	0	0	0	0	0
Margin (dB)	6	6	6	6	6	6	6	6
Signal required at aircraft (dBm)	-95	-93.5	-93.5	-91	-87.5	-92.3	-93.5	-93.5

(1) High rate azimuth function.

Table G-3. Interrelationship of ground equipment monitor and control action

Sub-system failure	Resultant action						
	Approach azimuth	Approach elevation	Flare	Back azimuth	Basic data word	DME or DME/P	Auxiliary data
Approach azimuth	*	*	*				
Approach elevation		*					
Flare			*				
Back azimuth				*			
Basic data word					*		
DME or DME/P						*	
Auxiliary data							*

* Indicates radiation should cease.

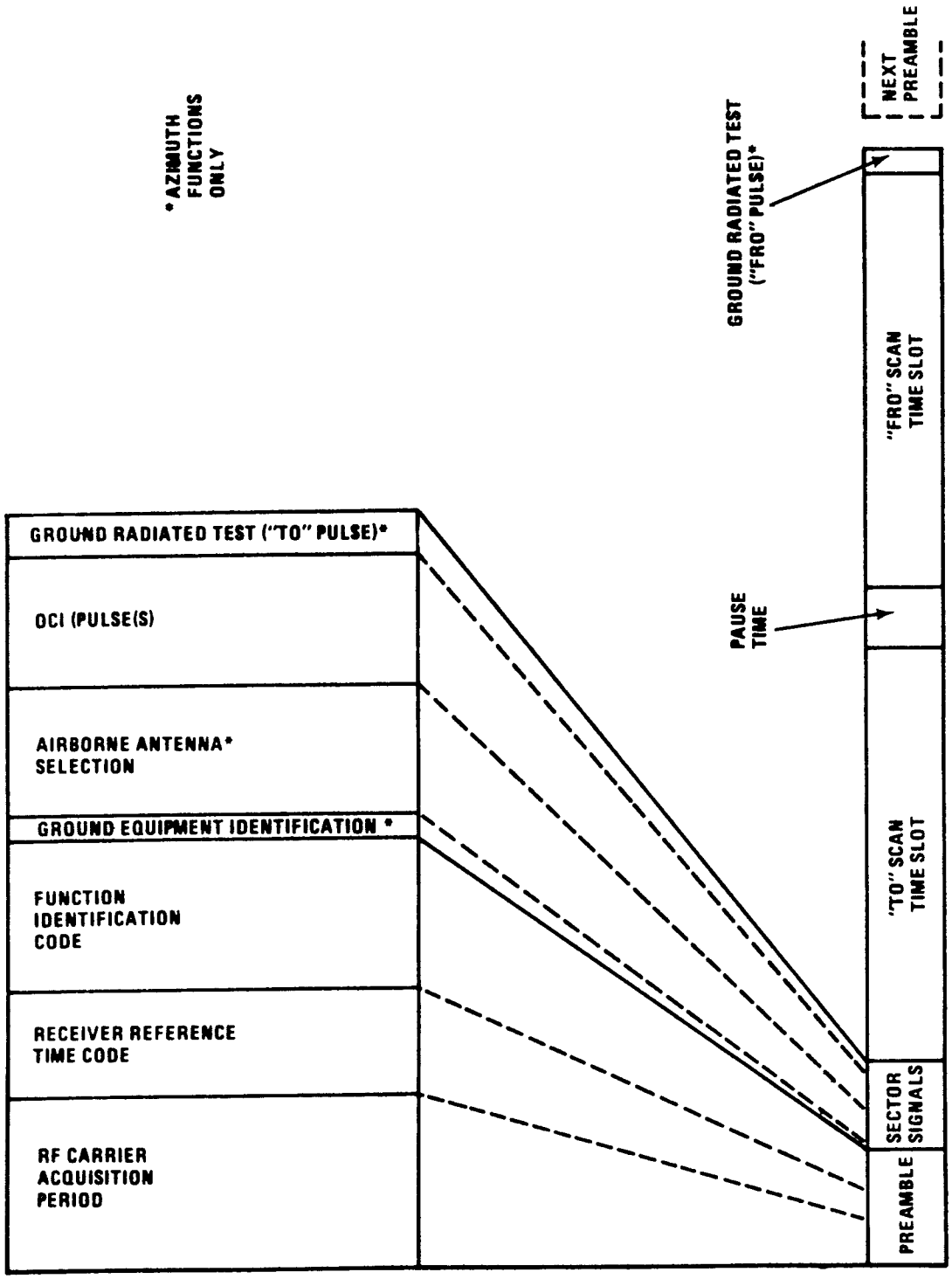


Figure G-1. Angle function organization

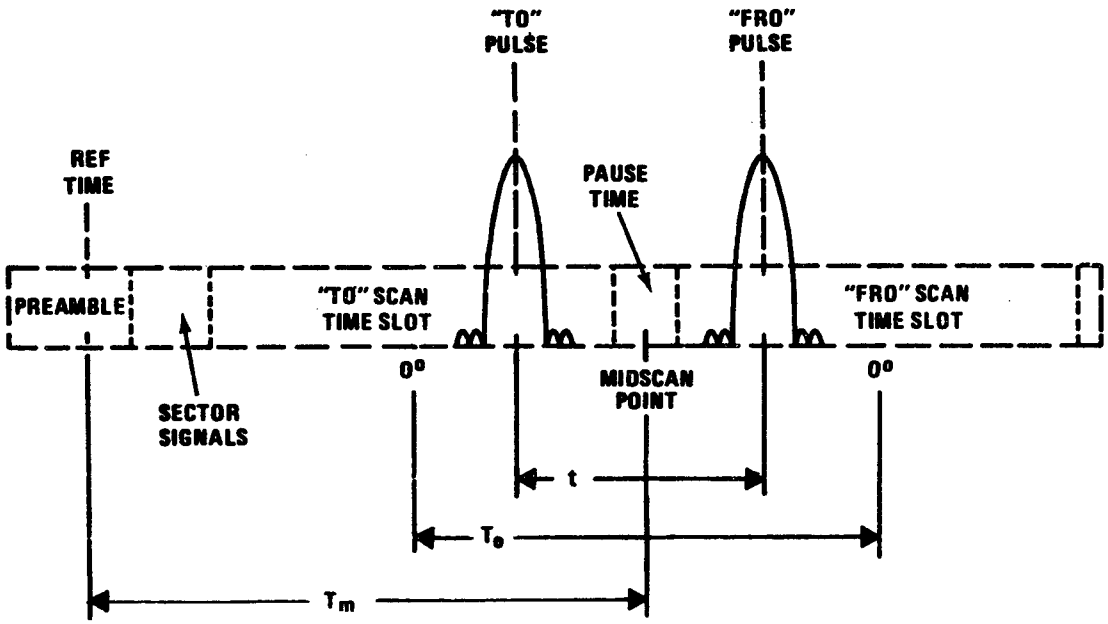
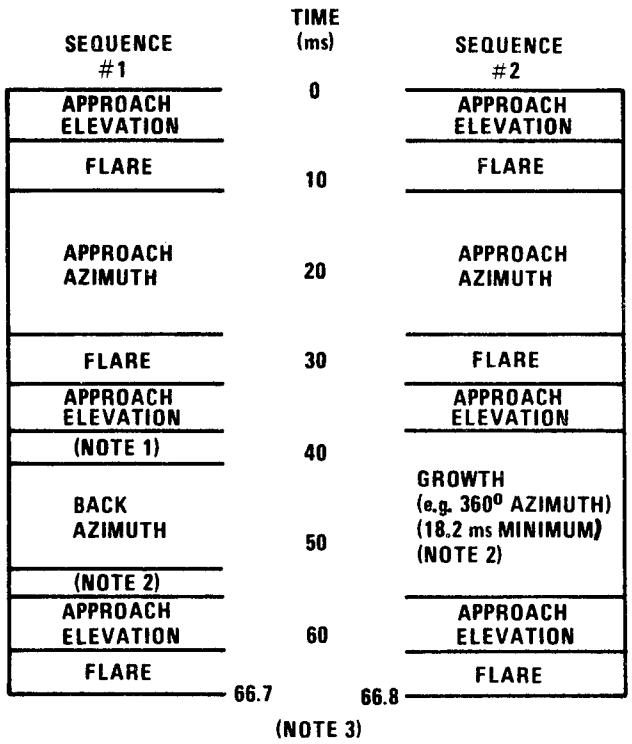


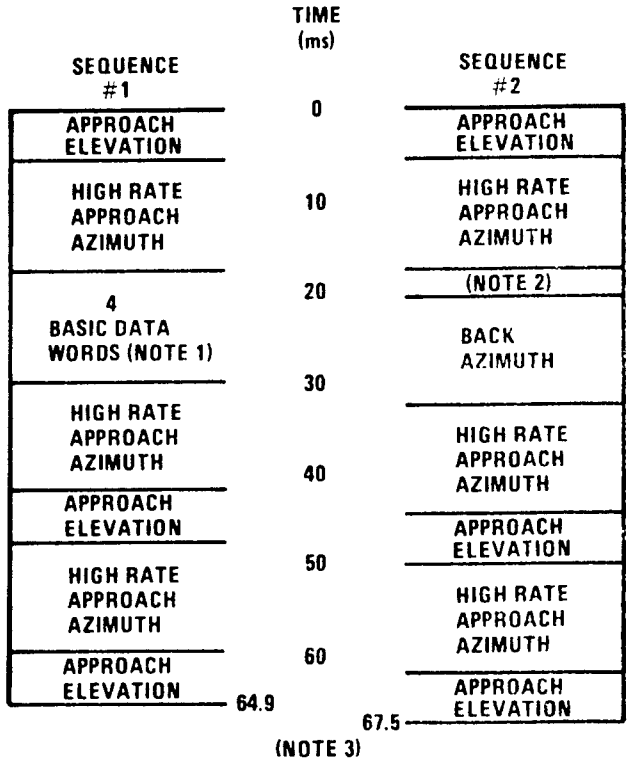
Figure G-2. Angle scan timing parameters



NOTES:

1. WHEN BACK AZIMUTH IS PROVIDED, BASIC DATA WORD #2 MUST BE TRANSMITTED ONLY IN THIS POSITION.
2. BASIC DATA WORDS MAY BE TRANSMITTED IN ANY OPEN TIME PERIODS.
3. THE TOTAL TIME DURATION OF SEQUENCE #1 PLUS SEQUENCE #2 MUST NOT EXCEED 134 ms.

Figure G-3A. Transmission sequence pair which provides for all MLS angle guidance functions



NOTES:

1. BASIC DATA WORDS MAY BE TRANSMITTED IN ANY OPEN TIME PERIODS.
2. WHEN BACK AZIMUTH IS PROVIDED, BASIC DATA WORD #2 MUST BE TRANSMITTED ONLY IN THIS POSITION.
3. THE TOTAL TIME DURATION OF SEQUENCE #1 PLUS SEQUENCE #2 MUST NOT EXCEED 134 ms.

Figure G-3B. Transmission sequence pair which provides for the MLS high rate approach azimuth angle guidance function

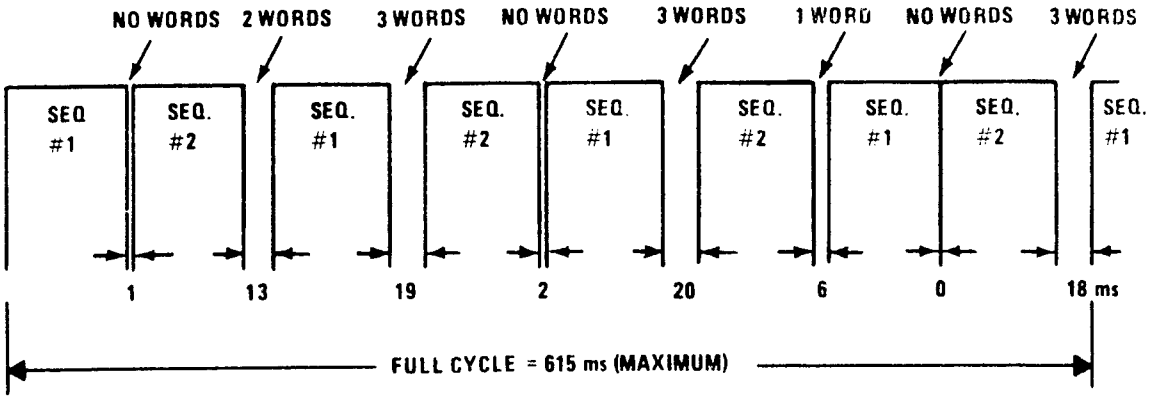


Figure G-3C. Complete multiplex transmission cycle showing open time periods available for auxiliary data words

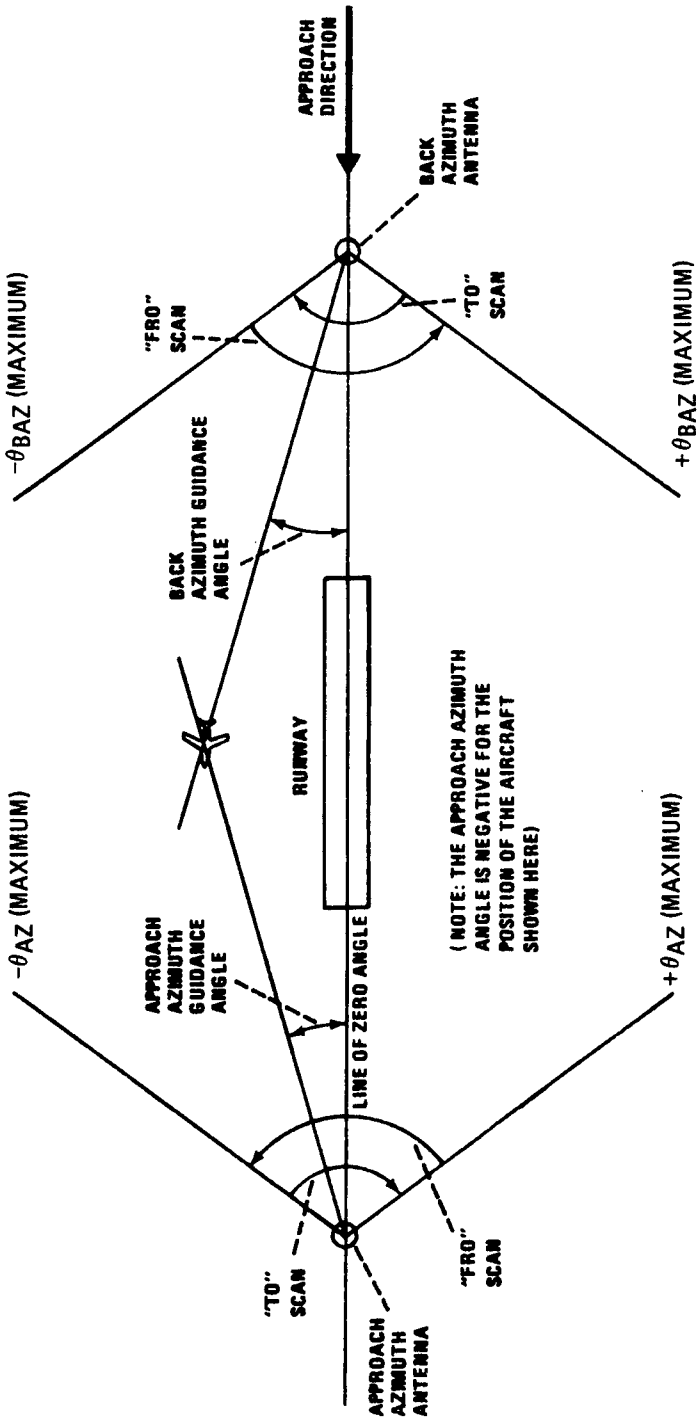


Figure G-4. Scanning conventions for azimuth guidance functions

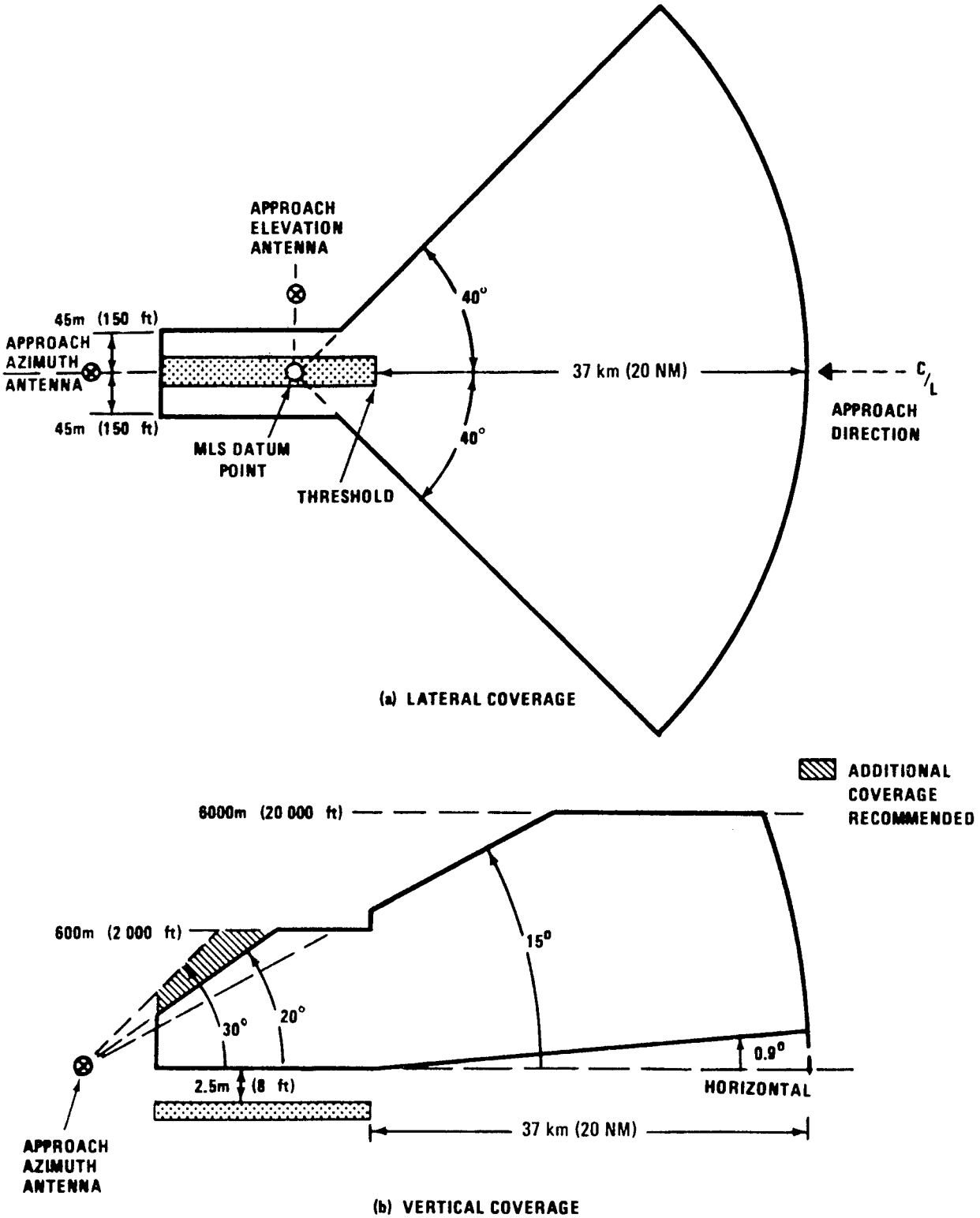


Figure G-5. Approach azimuth coverage

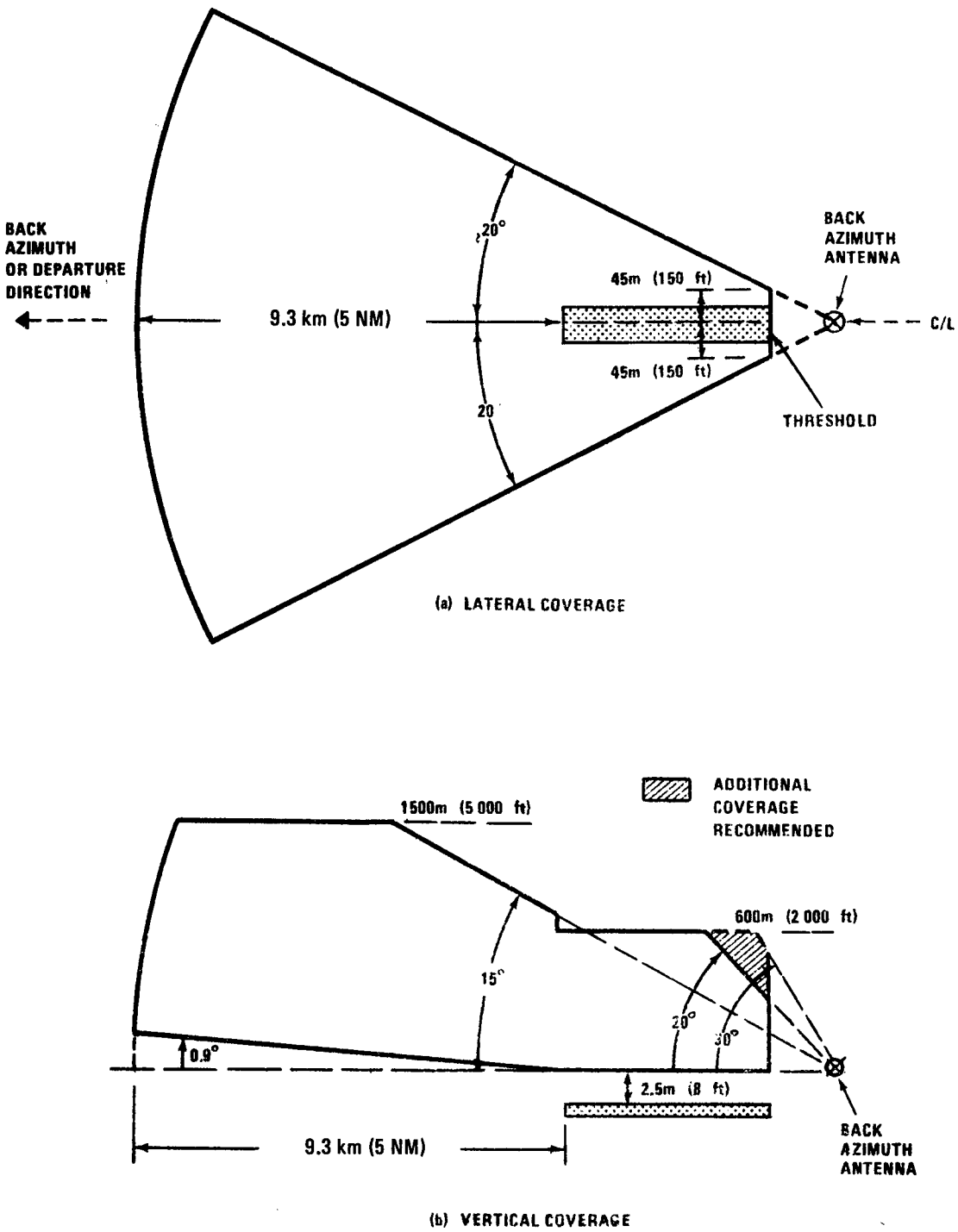


Figure G-6. Back azimuth coverage

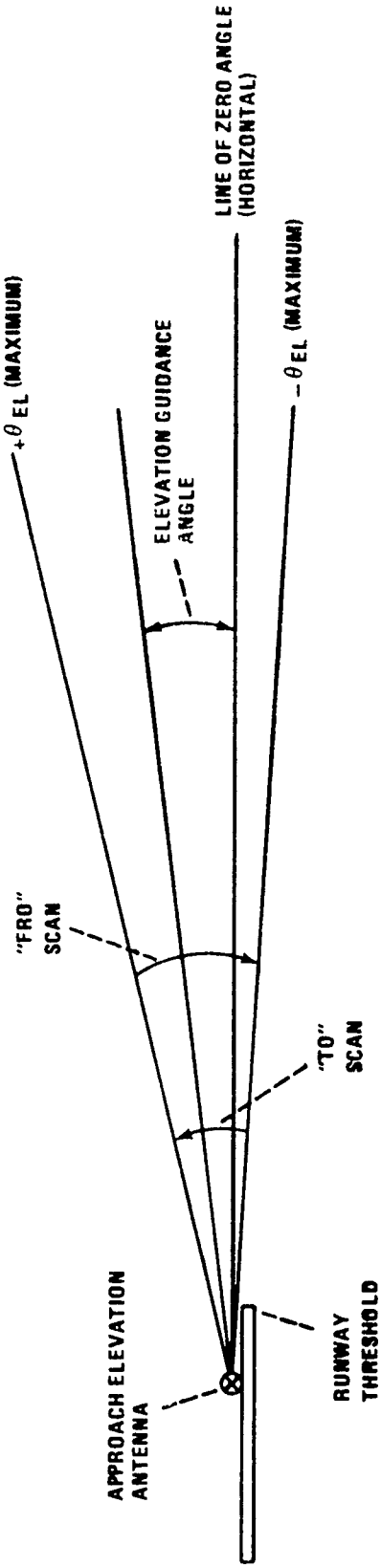
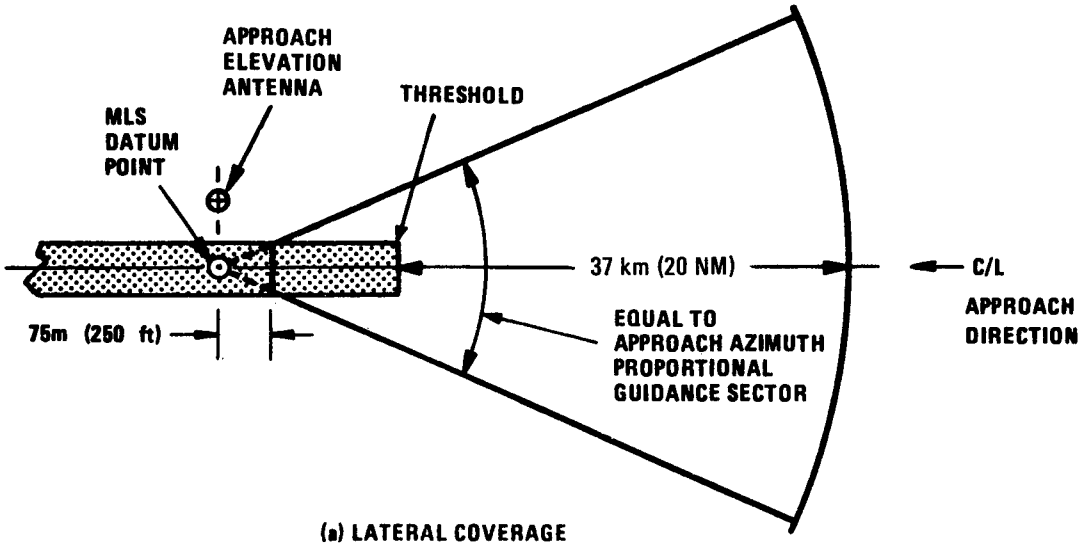
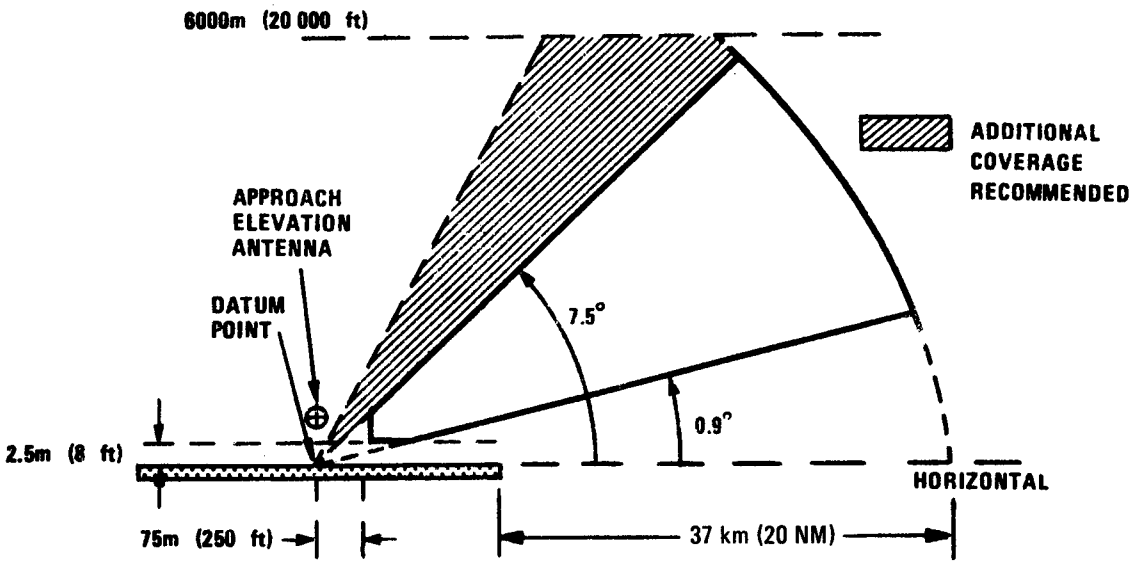


Figure G-7. Scanning conventions for approach elevation and flare guidance functions



(a) LATERAL COVERAGE



(b) VERTICAL COVERAGE

Figure G-8. Approach elevation coverage

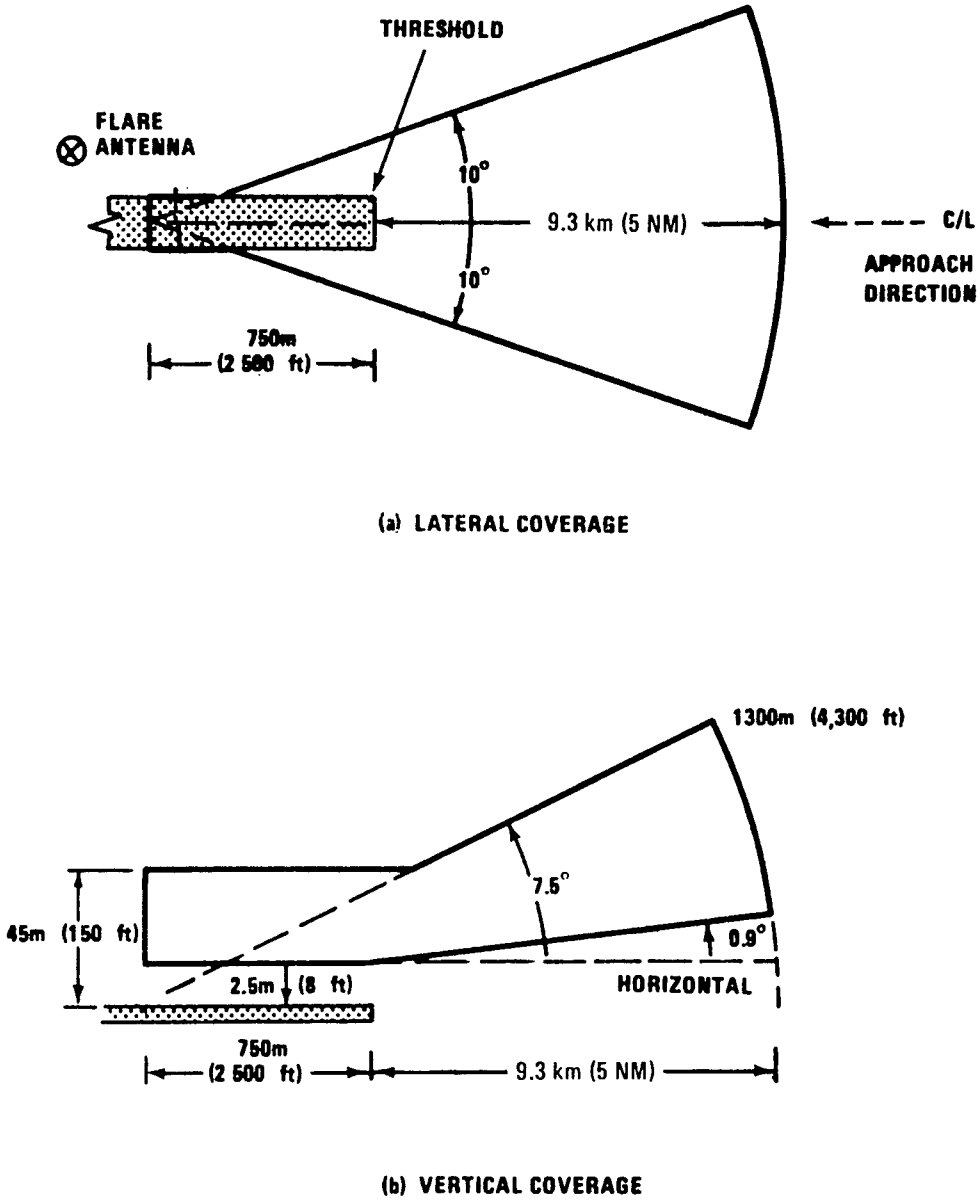
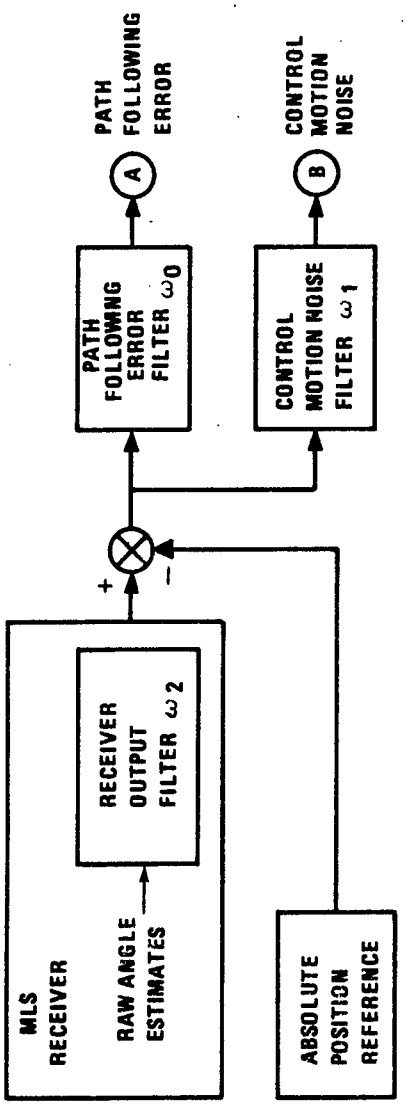


Figure G-9. Flare coverage



RECEIVER OUTPUT FILTER $\frac{\omega_2}{S+\omega_2}$

PATH FOLLOWING FILTER $\frac{\omega_n^2}{S^2 + 2\zeta\,\omega_n\,S + \omega_n^2}$ $\zeta = 1;\ \omega_0 = .64\,\omega_n$

CONTROL MOTION NOISE FILTER: $\frac{S}{S+\omega_1}$

GUIDANCE FUNCTION	CORNER FREQUENCIES (RADIANS/SEC)		
	ω 0	ω 1	ω 2
APPROACH AZIMUTH	0.5	0.3	10
APPROACH ELEVATION	1.5	0.5	10
FLARE	2.0	0.5	10

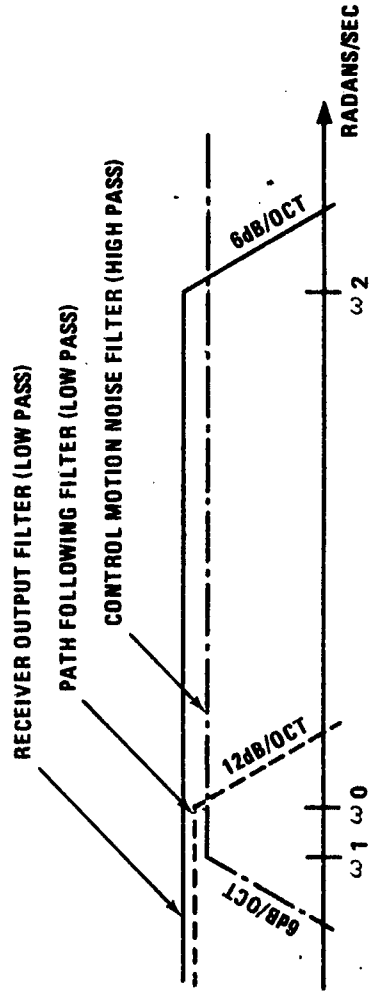
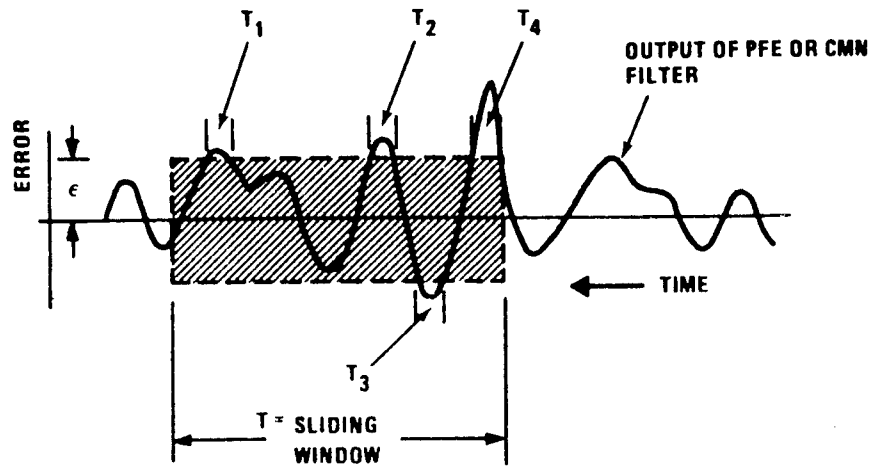


Figure G-10. Filter configurations and corner frequencies



NOTES:

ϵ = ERROR SPECIFICATION

T = REGION TO BE EVALUATED

$T_1\ T_2\ T_3 \ldots$ = TIME INTERVALS THAT ERROR EXCEEDS SPECIFICATIONS. FOR THE GROUND EQUIPMENT TO BE ACCEPTABLE IN THIS REGION, THE FOLLOWING INEQUALITY SHOULD BE TRUE:

$$\frac{(T_1 + T_2 + T_3 + \ldots)}{T} \leq 0.05$$

Figure G-11. MLS measurement methodology

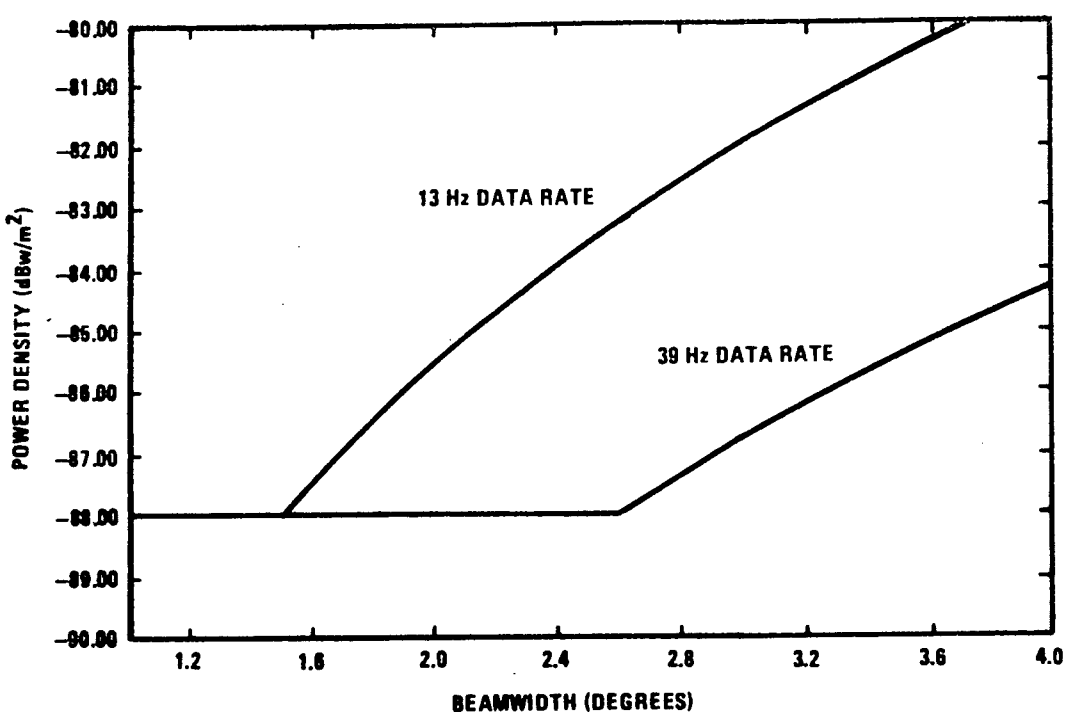
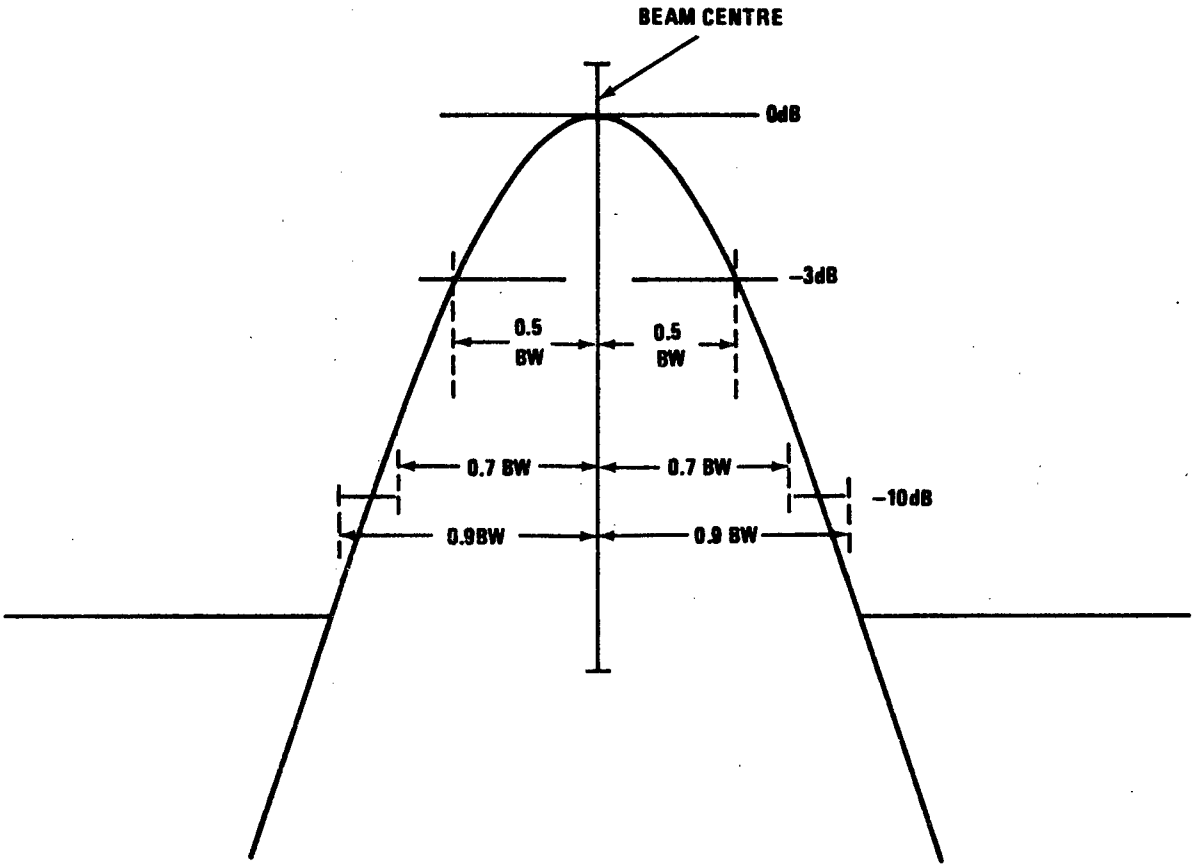


Figure G-12. Power density requirements for various antenna beamwidths



NOTES:

THE BEAM ENVELOPE IS SMOOTHED BY A 26 kHz VIDEO FILTER BEFORE MEASUREMENT.

BW = BEAMWIDTH.

Figure G-13. Far field dynamic signal-in-space

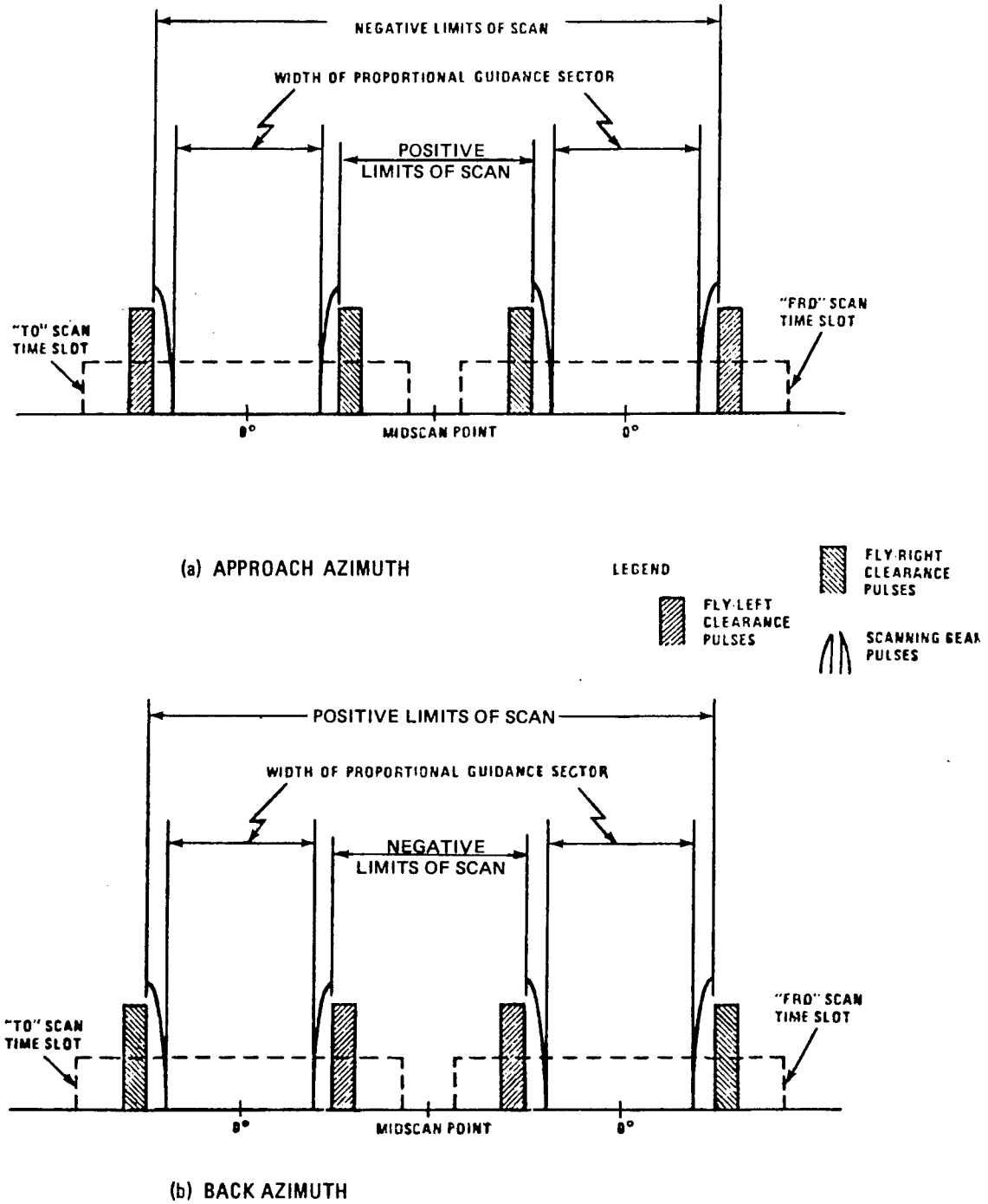
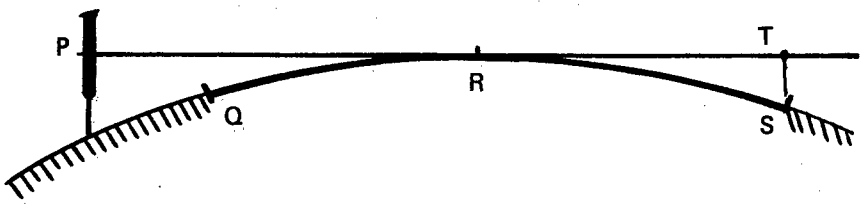


Figure G-14. Clearance pulse conventions for azimuth functions



P: azimuth antenna phase centre

Q: stopend

R: point of contact of tangent PR with runway (this point may be constructed on a vertical scale diagram derived from the longitudinal profile of the runway; typical horizontal scale 1 cm for 100 m; typical vertical scale 1 cm for 1 m).

S: runway threshold

T: point above threshold on extension of PR. (see paragraph 2.3.6).

Figure G-15. Lower coverage limit determination

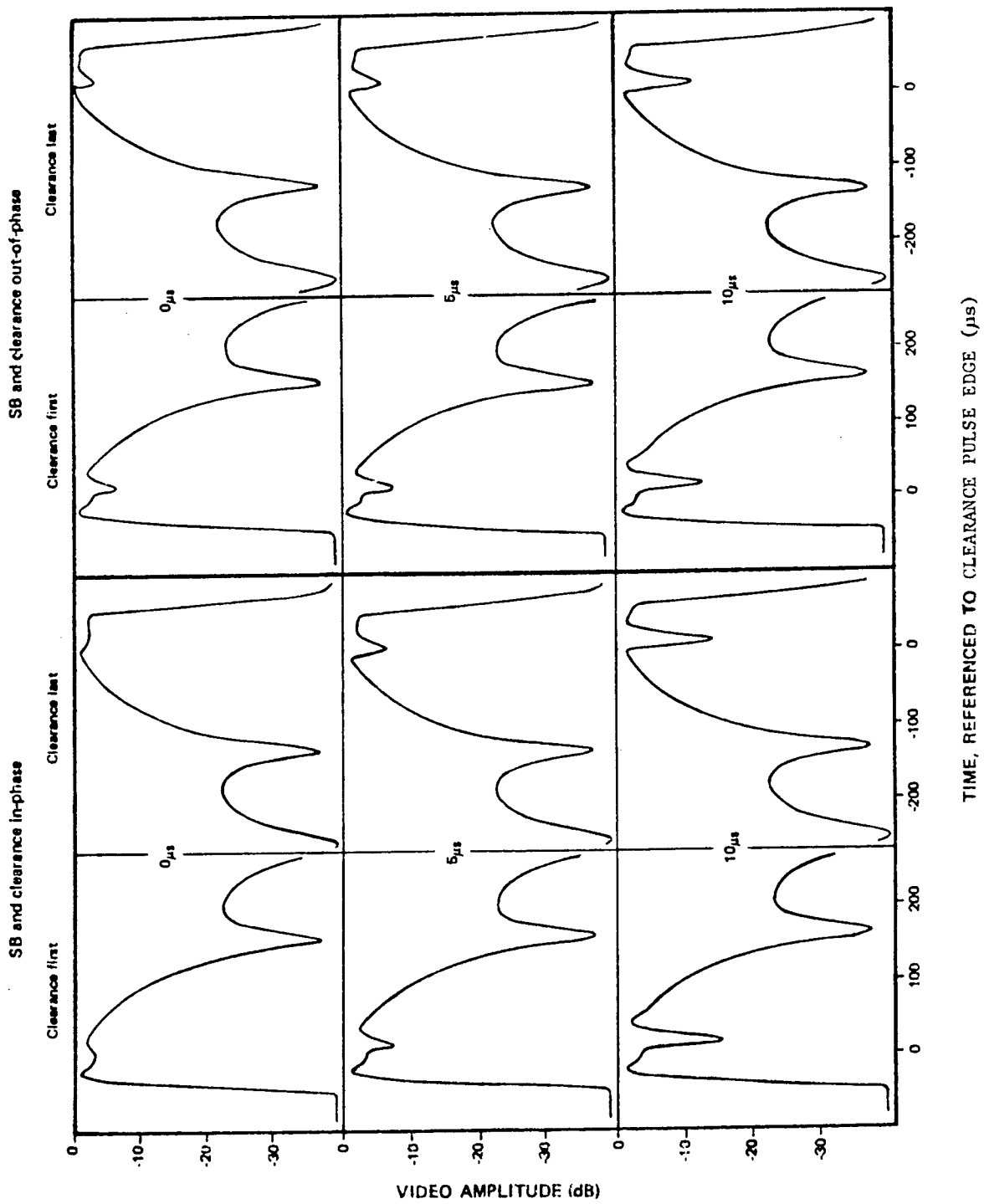


Figure G-16. Examples of received video waveforms in SB/clearance transition region for switching times of 0, 5 and 10 microseconds

ATTACHMENT A TO PART II. — CONSIDERATIONS AFFECTING THE DEPLOYMENT OF VHF COMMUNICATION FREQUENCIES

Introduction

Paragraphs 4.1.5.2 and 4.1.5.3 of Part II specify the geographical separation required for co-channel operation of VHF facilities in the Aeronautical Mobile Service. In Figure A-1 the distance AB indicates the separation required in order that aircraft *a* and *b* operating at the protection heights and at the limits of the functional service range of stations A and B respectively, will not experience harmful interference.

Paragraph 4.1.6.1 of Part II recommends the maximum antenna gain outside the main beam of facilities which provide service beyond the radio horizon. Figure A-2 illustrates the azimuthal angle to be protected and the method of derivation. Smaller beamwidths than 30 degrees are not considered practical at present.

Note.— The term "main beam" includes all azimuths where antenna gain exceeds 3 dB above that of a dipole.

1. Criteria employed in establishing adjacent channel frequency deployment with respect to receiver rejection and other system characteristics

1.1 For aircraft receivers designed for operation in a 50 kHz channel spacing environment and a ground station frequency tolerance of 50 parts in 10^6 (plus or minus 0.005 per cent), an effective adjacent channel rejection characteristic of 60 dB or better is assumed. This assumption will result in a geographical separation distance between the nearest limits of the functional service ranges of the two facilities of at least 5.6 km (3 NM).

1.2 For aircraft receivers designed for operation in a 25 kHz channel spacing environment and a ground station frequency tolerance of plus or minus 0.002 per cent, an effective adjacent channel rejection characteristic of 60 dB or better is assumed. This assumption will result in a geographical separation distance between the nearest limits of the functional service ranges of the two facilities of at least 5.6 km (3 NM).

1.3 The above criteria are based on the concept of protection by receiver muting, except in the case of area control and FIR channels where a minimum field strength is specified in order to secure the desired wanted-to-unwanted signal ratio.

1.4 The following additional assumptions were made in establishing the criteria:

1) *Propagation:* free space propagation between aircraft. The CCIR curves for 100 MHz vertical polarization over land in conjunction with an assumed ground antenna height of 20 m (65 ft) were used in computing ground-air field strengths.

2) *Minimum field strength at limit of functional service range:* 45 dB above 1 microvolt per metre at 3 000 m (10 000 ft) in the case of area control and FIR channels.

   Note.— To meet this requirement, a station radiating 100 W from an antenna 20 m (65 ft) high should be not more than 185 km (100 NM) from the limit of its functional service range.

3) *Effective radiated power (ERP)*: a maximum ERP of 20 W from ground and airborne stations with the exception that, in case of ground stations providing flight information or area control service communications, it was necessary to assume a minimum ERP of 100 W.

4) *Airborne antenna polar patterns:* total variations not exceeding 10 dB. Since a maximum ERP was assumed

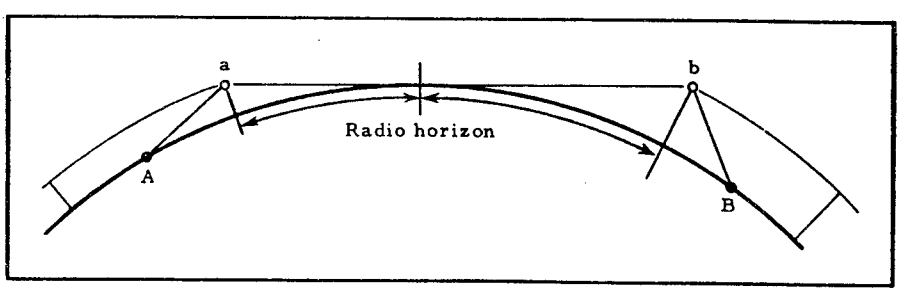


Figure A-1. Geographical separation required for co-channel operation of VHF facilities

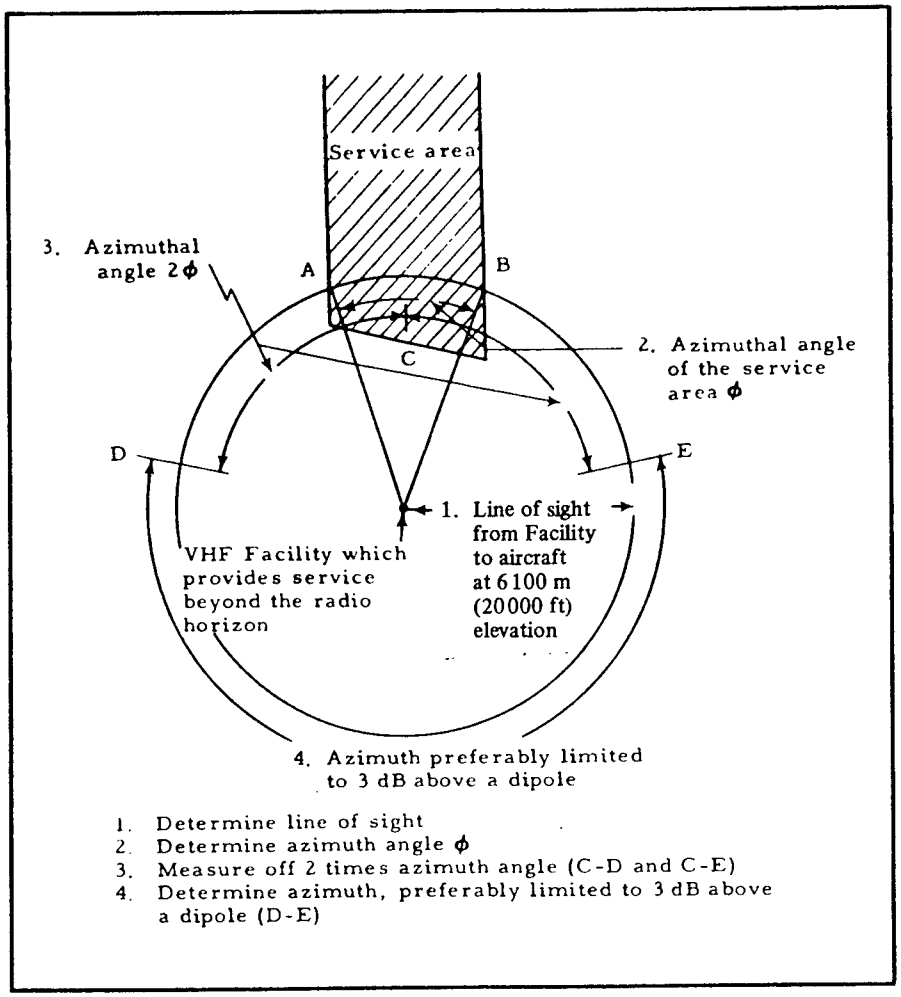


Figure A-2. Limit of azimuth protection for VHF facilities which provide a service beyond the radio horizon

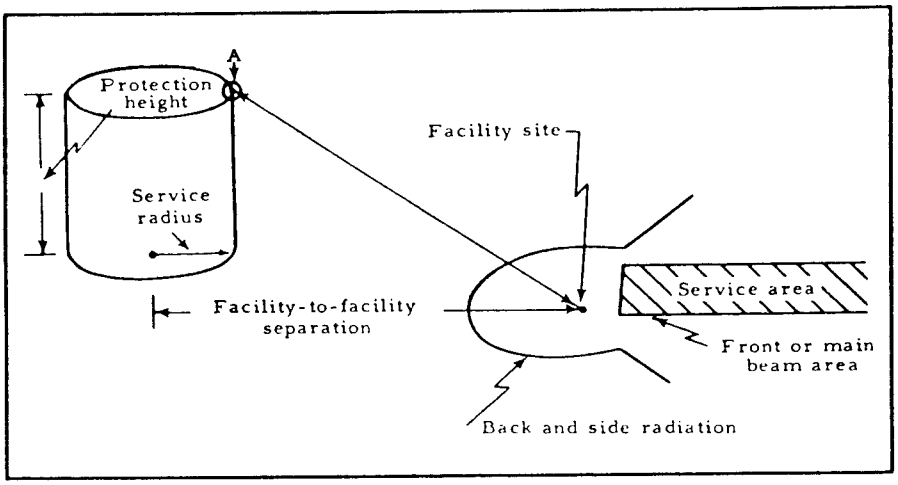


Figure A-3. Air-to-ground (facility from A) and ground-to-air (A from facility)

(and therefore all variations are downwards from this figure), no allowance was necessary in respect of airborne transmitter polar diagrams.

5) *Wanted-to-unwanted signal ratio:* 20 dB at the receiver output.

6) *Receiver muting characteristics:* a muting threshold corresponding to a received field strength of 5 microvolts per metre.

2. Criteria to be employed in establishing adjacent channel frequency deployment of VHF facilities that have a service range beyond the radio horizon

For the most economical use of frequencies and to ensure freedom from interference, planning must be based on an accurate knowledge of equipment used. When the equipment characteristics and field strength (or attenuation) curves are on hand for the troposcatter regions, it is relatively easy to determine the required geographical separation. When these are not known, the maximum permitted antenna gain stipulated in Part II, 4.1.6.1 will be assumed. There are several conditions that must be calculated and compared to determine the appropriate separation to be used. The conditions to be compared are:

1) ground facility-to-aircraft;

2) aircraft-to-ground facility;

3) aircraft-to-aircraft;

4) ground facility-to-ground facility.

Case 1.— For the case of protection of aircraft A from a ground facility (see Figure A-3):

A. Determine the signal level S (dB rel. 1 μV/m) received from the desired station at the limit of the service radius at the protection altitude.

B. Assign the desired protection ratio P (dB) required at the aircraft receiver.

C. Let receiver adjacent channel rejection be represented by A (dB). Then the level L (dB rel. 1 μV/m) that can be tolerated at the receiver antenna can be determined by:

$$L = S - P + A$$

D. Distance d (km) from protection point to undesired facility to provide protection established by "C" above, is found by application of L to the appropriate curves.*

E. The facility-to-facility separation D is d (km) plus service radius (km).

**Note 1.-- Figures A-7 to A-14 are field strength curves appropriate for the average temperate climate over land or sea, which may be used to determine geographical separation for situations where these field strengths will not normally be exceeded more than 5 per cent of the time. These curves were established by the Institute for Telecommunications Sciences and Aeronomy of the Environmental Science Services Administration of the United States of America.*

Note 2.— For power levels other than 1 kW the necessary corrections under "C" above would have to be made. For example, 5 kW ERP requires a minus 7 dB correction.

Case 2.— Aircraft (A)-to-ground facility (see Figure A-3):

A. Determine signal level Sg at the ground facility receiving antenna for proper system operation.

B. Proceed as in Case 1, where

$$L = Sg - P + A$$

C. Ground facility-to-ground facility separation will also be determined as in Case 1 (D = d + service radius).

Note.— Where ground facility receivers have sensitivities of less than 1 microvolt across 50 ohms, Case 2 is most likely to yield the separation to be used.

Case 3.— Aircraft (A)-to-aircraft (B) (see Figure A-4):

A. Establish service radius and protection altitude for facility to be protected (see aircraft A in Figure A-4).

B. Determine closest point to aircraft A that aircraft B will be transmitting to the ground facility site and the altitude where this will take place.

C. Proceed as in Case 1, using the aircraft (B) contacting ground facilities as the undesired signal.

D. Then $L = S - P + A$

E. The distance d to aircraft B (undesired) obtained from the curves, plus the service radius of the facility to be protected, will determine the separation between aircraft B and the ground facility protected.

F. Facility-to-facility separation may then be determined graphically or by trigonometric means.

Case 4.— Ground facility-to-ground facility (see Figure A-4).

A. Determine signal level that can be tolerated at the receiver antenna at one facility by $L = Sg - P + A$ (see Case 1).

B. Then facility-to-facility separation for these conditions is read directly from the curves (after correcting for transmitter power of other facilities if different from 1 kW).

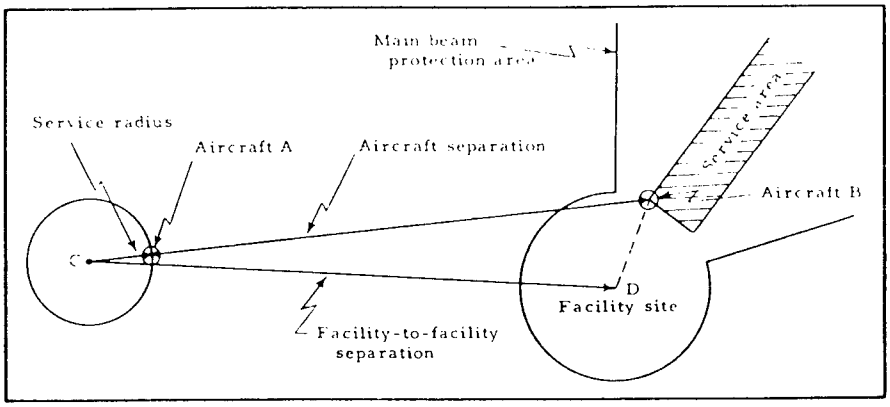


Figure A-4. Facility-to-facility separation based on air-to-air (A from B) and ground-to-ground (C from D)

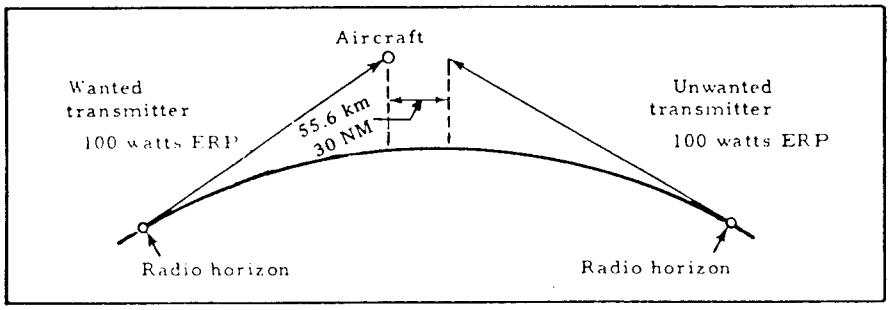


Figure A-5. VOLMET planning (illustrating co-channel protection)

C. Should equipments at the two facilities have different characteristics, repeat procedure in "A" and "B" above for the other combination of equipments.

D. Of the two distances derived, use the greater to compare with other cases (see below).

Note.— In most instances, it will be found that the facility-to-facility consideration will not be the controlling factor in determining geographical separation.

Facility separation will then be the greatest distance derived for Cases 1 to 4.

3. Criteria to be employed in establishing geographical separation between ground stations and between aircraft and ground stations for co-channel operation of VHF facilities that have a service area beyond the radio horizon

Geographical separation of co-channel facilities can be calculated by using the method given in 2 above except that the adjacent channel rejection (A) is omitted from consideration.

4. Criteria employed in establishing co-channel frequency deployment of VHF VOLMET facilities

In the case of VHF VOLMET services, the geographical separation between co-channel stations should be 55.6 km (30 NM) plus twice the distance to the radio horizon from an aircraft at the highest altitude flown by aircraft in the area concerned.

Note.— At 27.9 km (15 NM) beyond the radio horizon, the field strength at 13 500 m (45 000 ft), from a transmitter of 100 W ERP, will be approximately at the receiver muting level of 5 microvolts per metre.

5. Criteria employed in establishing adjacent channel frequency deployment of VHF VOLMET facilities

5.1 For aircraft receivers designed for operation in a 25 kHz channel spacing environment, an effective adjacent channel rejection characteristic of 60 dB or better is assumed. This assumption will result in a geographical separation distance (D) between VHF VOLMET ground transmitters derived as follows (nautical miles may be substituted for kilometres):

$$D = (d_1 + d_2) \text{ km}$$

where

d_1 = distance between aircraft and wanted ground station

= radio horizon + 27.8 km (15 NM)

and

d_2 = distance between aircraft and unwanted ground station

= 24.1 km (13 NM).

5.2 Where it is necessary to take account, on a regional basis, of receivers not specifically designed for 25 kHz channel spacing and used in a 25 kHz channel spacing environment, an effective adjacent channel rejection characteristic of the receiver of the order of 40 dB is assumed. This assumption will result in a minimum geographical separation distance (D) between VHF VOLMET ground transmitters derived as follows:

$$D = (d_1 + d_2) \text{ km}$$

where

d_1 = distance between aircraft and wanted ground station

= radio horizon + 27.8 km (15 NM)

d_2 = distance between aircraft and unwanted ground station

= 240.9 km (130 NM).

5.3 Application of the above criteria in the case of aircraft altitudes of 13 500 m (45 000 ft) and 20 000 m (66 000 ft) results in the following separation distances:

Altitude	*Receiver rejection characteristic*	*d_1 km (NM)*	*d_2 km (NM)*	*D km (NM)*
13 500 m (45 000 ft)	60 dB	491 (265)	24.1 (13)	515 (278)
13 500 m (45 000 ft)	40 dB	491 (265)	241 (130)	732 (395)
20 000 m (66 000 ft)	60 dB	619 (334)	24.1 (13)	643 (347)
20 000 m (66 000 ft)	40 dB	619 (334)	241 (130)	860 (464)

5.4 The above criteria are based on the following additional assumptions:

1) *Effective radiated power:* an ERP of 100 W for the ground stations.

Note.— If an ERP of 20 W is assumed, this would result in separation distances for 13 500 m (45 000 ft) of 472 km (255 NM) for 60 dB receiver adjacent channel rejection and 572 km (309 NM) for 40 dB receiver adjacent channel rejection.

2) *Interfering signal strength:* if the received signal strength is in excess of the free space propagation value, then the maximum value will not exceed the free space value by more than 5 dB over average earth. This condition is satisfied when transmitters of 20 W ERP or more are used in conjunction with a receiver adjacent channel rejection of not less than 35 dB. Thus, the minimum distance for d_2 can be derived from a consideration of receiver muting level, receiver adjacent channel rejection and transmitter ERP.

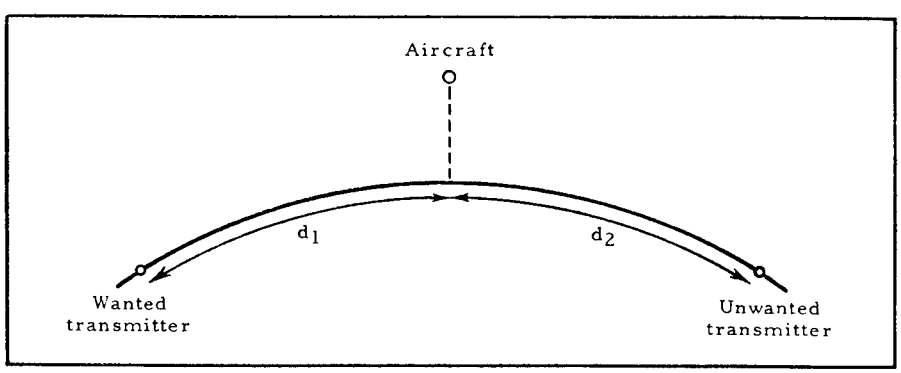


Figure A-6. VOLMET planning (illustrating adjacent channel protection)

Figures A-7 to A-14. Propagation curves for standard atmosphere (301) for frequency of 127 MHz

ESSA/I.T.S.A. — 1966 Propagation Model

These curves labelled "5 per cent time availability" represent only a statistically expected value; *i.e.*, a probability of 0.05 that a particular situation will result in the specified field strength or greater during 5 per cent of the time.

The parameters used to develop these curves include:

1) frequency of 127 MHz;

2) horizontal or vertical polarization;

3) smooth earth with land or sea surface;

4) reflection coefficient of unity magnitude;

5) standard atmosphere with a 301 surface refractivity;

6) continental temperate climate;

7) Nakagami-Rice statistics for within-the-horizon fading;

8) An effective radiated power (ERP) corresponding to 1 kilowatt input power into a lossless half-wave dipole.

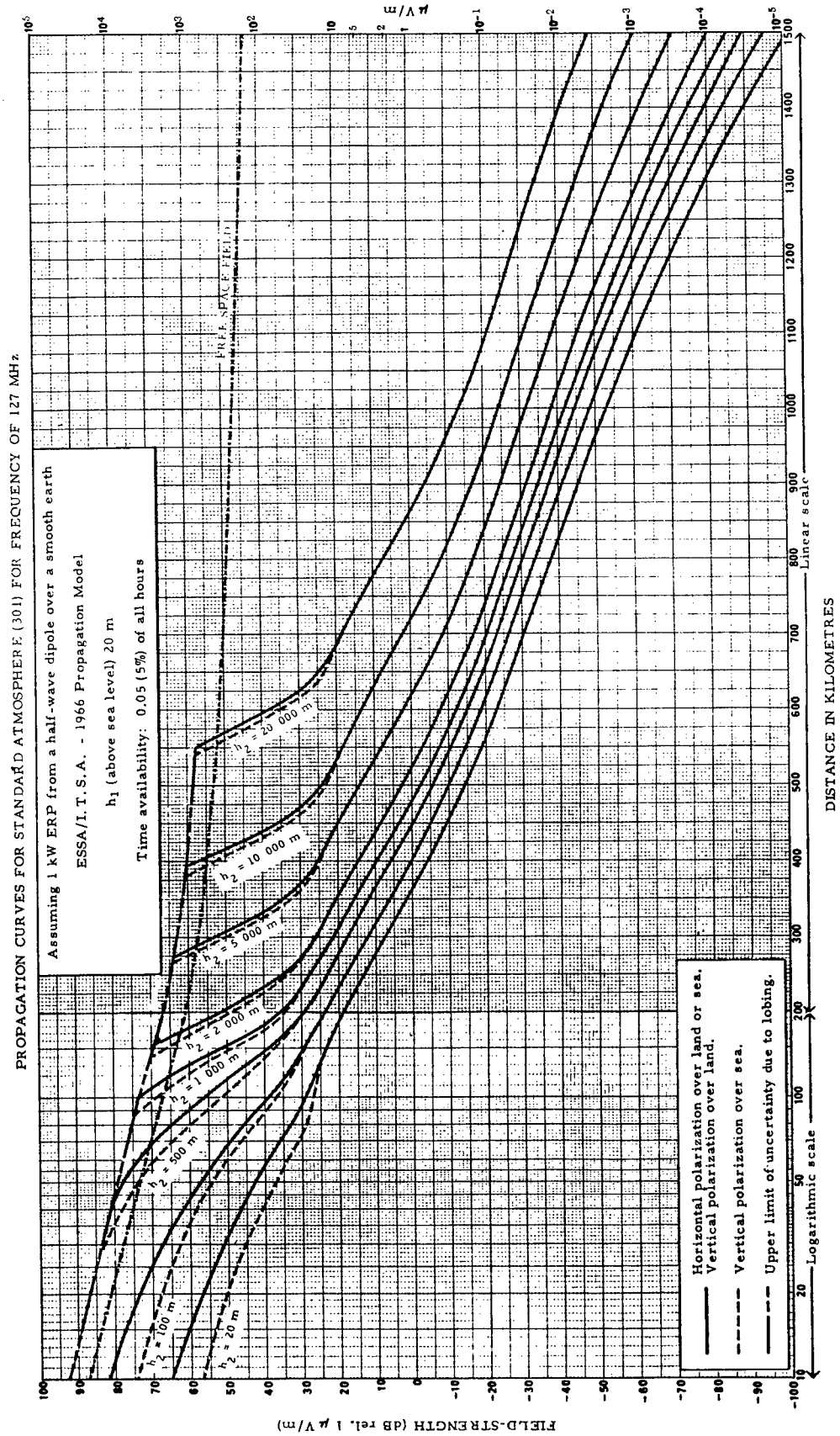

PROPAGATION CURVES FOR STANDARD ATMOSPHERE (301) FOR FREQUENCY OF 127 MHz
Assuming 1 kW ERP from a half-wave dipole over a smooth earth
ESSA/I.T.S.A. - 1966 Propagation Model
h1 (above sea level) 20 m
Time availability: 0.05 (5%) of all hours
FREE SPACE FIELD
h2 = 20 000 m
h2 = 10 000 m
h2 = 5 000 m
h2 = 2 000 m
h2 = 1 000 m
h2 = 500 m
h2 = 100 m
h2 = 20 m
Horizontal polarization over land or sea.
Vertical polarization over land.
Vertical polarization over sea.
Upper limit of uncertainty due to lobing.
Logarithmic scale
Linear scale
DISTANCE IN KILOMETRES
FIELD-STRENGTH (dB rel. 1 μV/m)
μV/m

Figure A-7

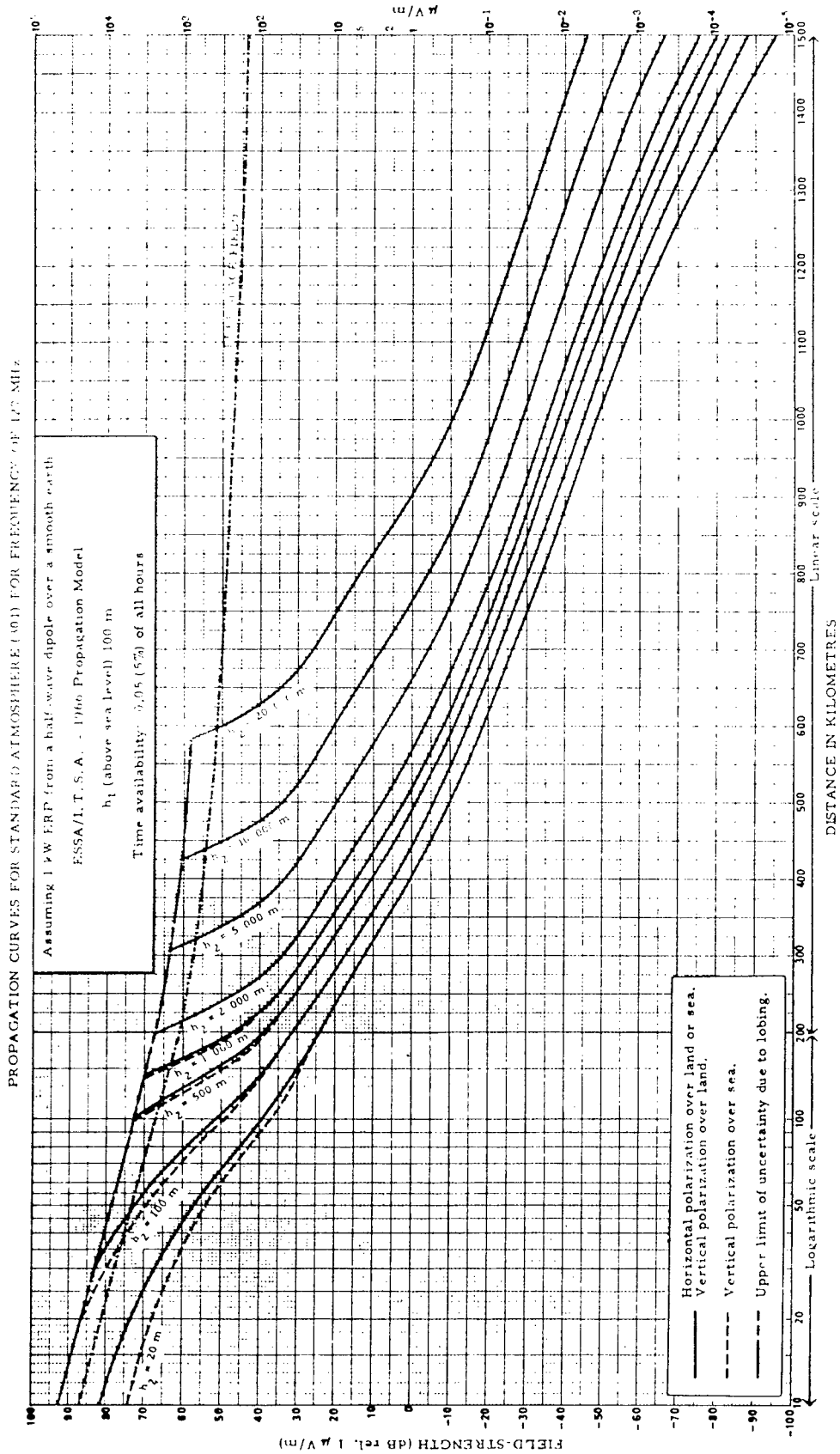

PROPAGATION CURVES FOR STANDARD ATMOSPHERE (N0) FOR FREQUENCIES OF 125 MHz
Assuming 1 kW ERP from a half-wave dipole over a smooth earth
ESSA/I. T. S. A. - 1966 Propagation Model
h_1 (above sea level) 100 m
Time availability: 0.05 (5%) of all hours
h_2 = 20 m
h_2 = 100 m
h_2 = 500 m
h_2 = 1 000 m
h_2 = 2 000 m
h_2 = 5 000 m
h_2 = 10 000 m
h_2 = 20 000 m
Horizontal polarization over land or sea.
Vertical polarization over land.
Vertical polarization over sea.
Upper limit of uncertainty due to lobing.
Logarithmic scale
Linear scale
DISTANCE IN KILOMETRES
FIELD-STRENGTH (dB rel. 1 μV/m)
μV/m

Figure A-8

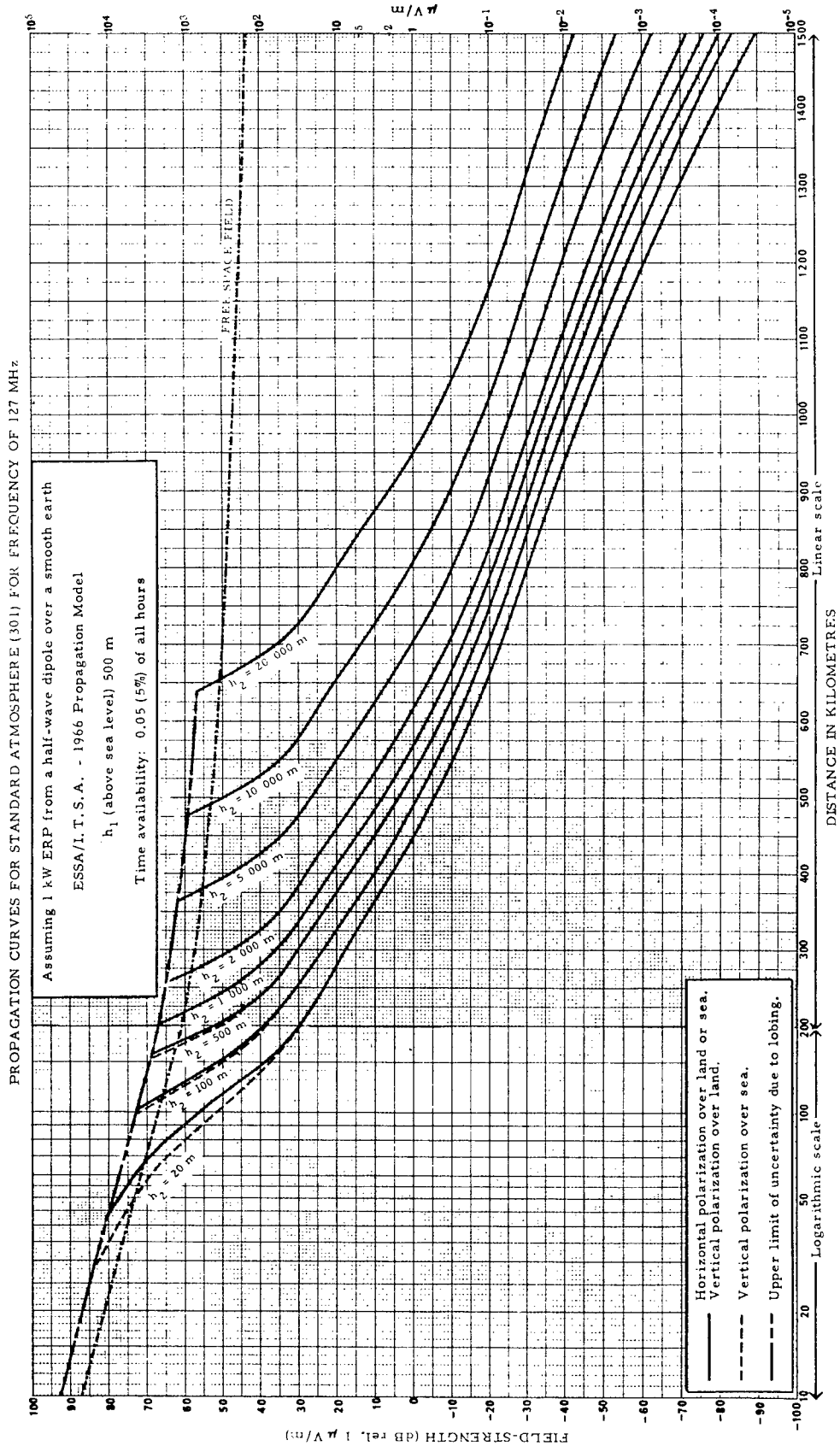

PROPAGATION CURVES FOR STANDARD ATMOSPHERE (301) FOR FREQUENCY OF 127 MHz
Assuming 1 kW ERP from a half-wave dipole over a smooth earth
ESSA/I.T.S.A. - 1966 Propagation Model
h1 (above sea level) 500 m
Time availability: 0.05 (5%) of all hours
FREE SPACE FIELD
h2 = 20 000 m
h2 = 10 000 m
h2 = 5 000 m
h2 = 2 000 m
h2 = 1 000 m
h2 = 500 m
h2 = 100 m
h2 = 20 m
Horizontal polarization over land or sea.
Vertical polarization over land.
Vertical polarization over sea.
Upper limit of uncertainty due to lobing.
FIELD-STRENGTH (dB rel. 1 μV/m)
μV/m
DISTANCE IN KILOMETRES
Logarithmic scale
Linear scale

Figure A-9

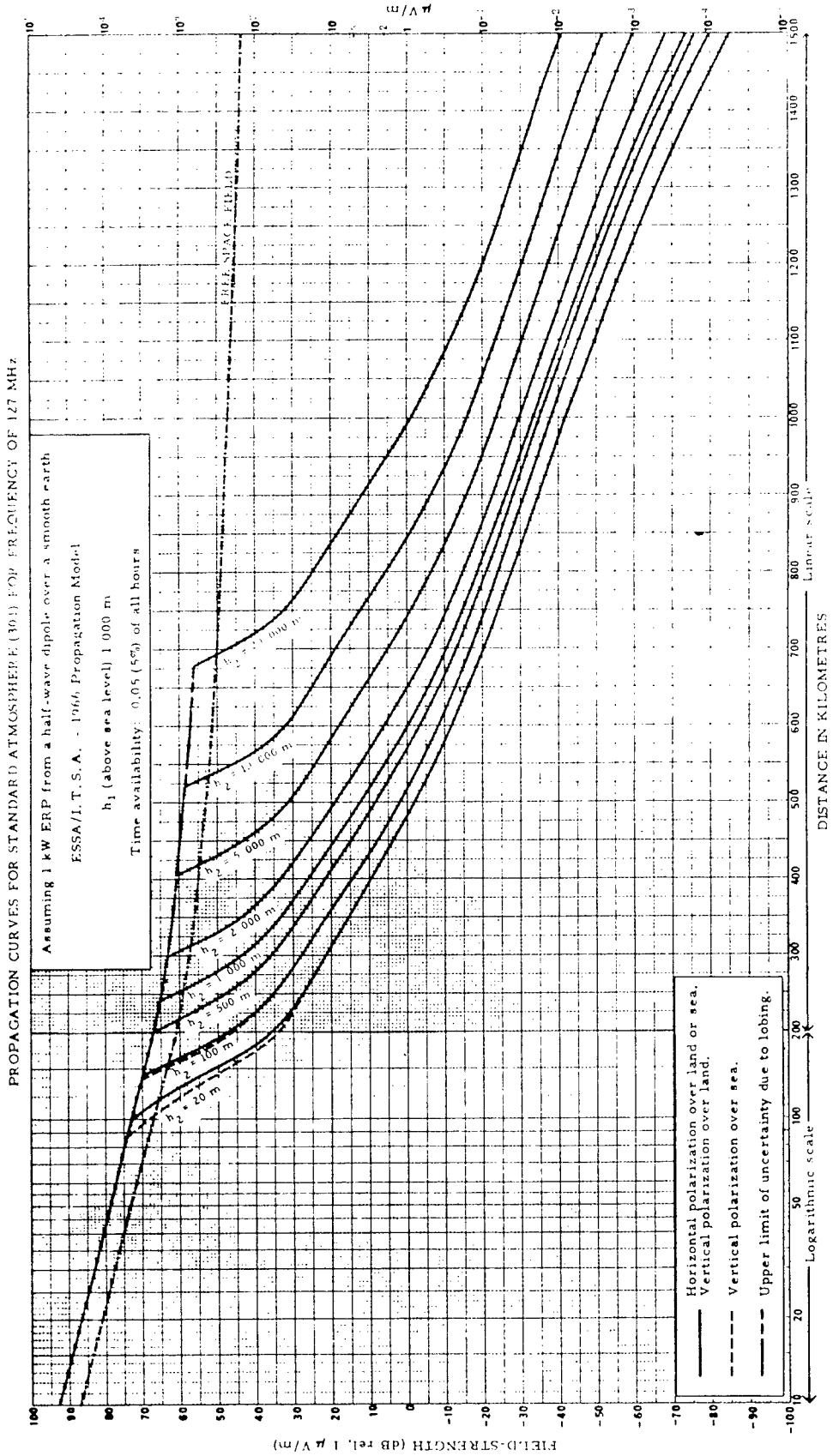

PROPAGATION CURVES FOR STANDARD ATMOSPHERE (301) FOR FREQUENCY OF 127 MHz
Assuming 1 kW ERP from a half-wave dipole over a smooth earth
ESSA/I. T. S. A. - 1966 Propagation Model
h_1 (above sea level) 1 000 m
Time availability: 0,05 (5%) of all hours
h_2 = 20 m
h_2 = 100 m
h_2 = 500 m
h_2 = 1 000 m
h_2 = 2 000 m
h_2 = 5 000 m
h_2 = 10 000 m
h_2 = 20 000 m
FREE SPACE FIELD
Horizontal polarization over land or sea.
Vertical polarization over land.
Vertical polarization over sea.
Upper limit of uncertainty due to lobing.
DISTANCE IN KILOMETRES
Logarithmic scale
Linear scale
FIELD-STRENGTH (dB rel. 1 μV/m)
μV/m

Figure A-10

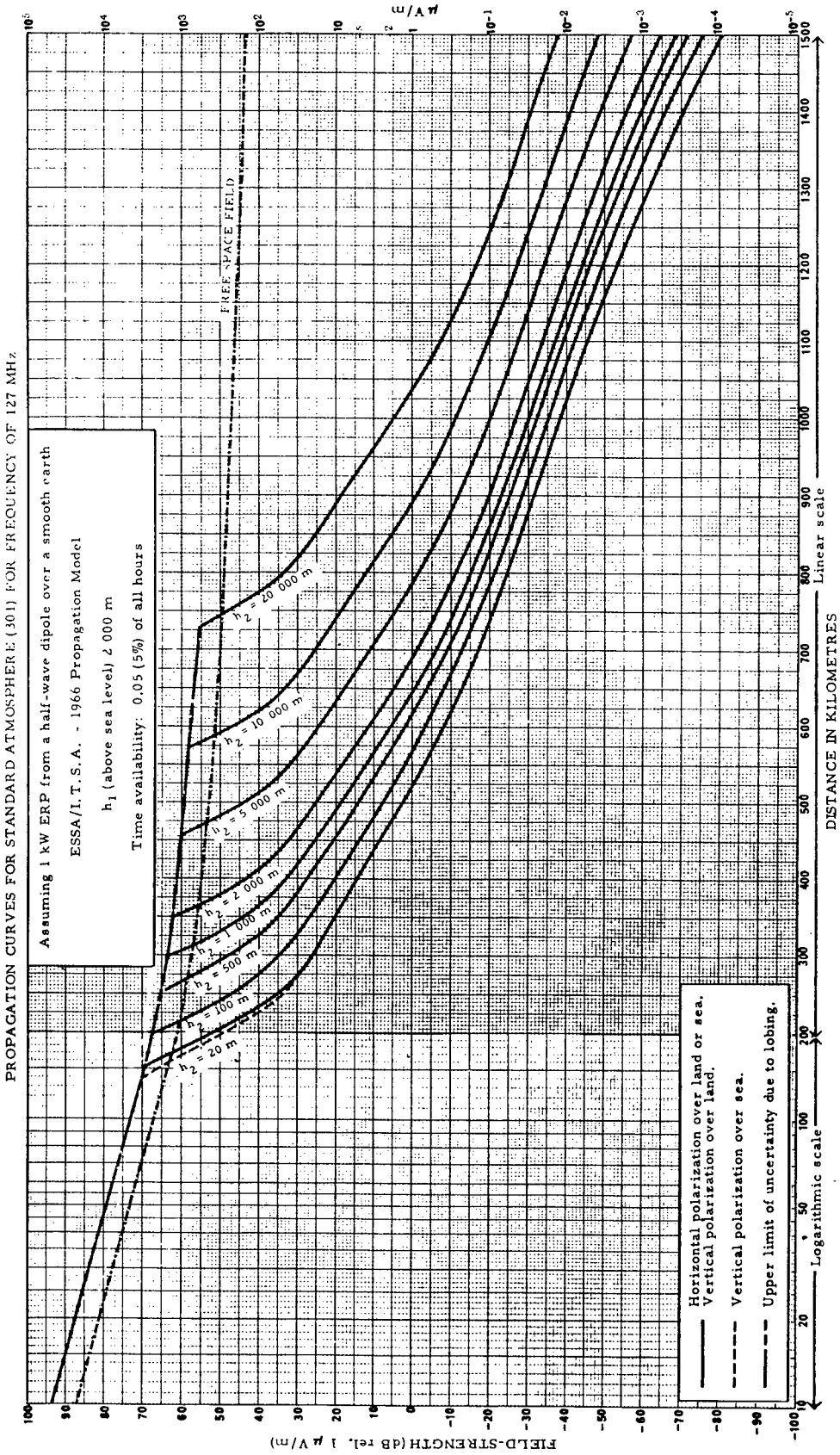

PROPAGATION CURVES FOR STANDARD ATMOSPHERE (301) FOR FREQUENCY OF 127 MHz
Assuming 1 kW ERP from a half-wave dipole over a smooth earth
ESSA/I.T.S.A. - 1966 Propagation Model
h1 (above sea level) 2 000 m
Time availability: 0.05 (5%) of all hours
FREE SPACE FIELD
h2 = 20 000 m
h2 = 10 000 m
h2 = 5 000 m
h2 = 2 000 m
h2 = 1 000 m
h2 = 500 m
h2 = 100 m
h2 = 20 m
Horizontal polarization over land or sea.
Vertical polarization over land.
Vertical polarization over sea.
Upper limit of uncertainty due to lobing.
μV/m
FIELD-STRENGTH (dB rel. 1 μV/m)
DISTANCE IN KILOMETRES
Logarithmic scale
Linear scale

Figure A-11

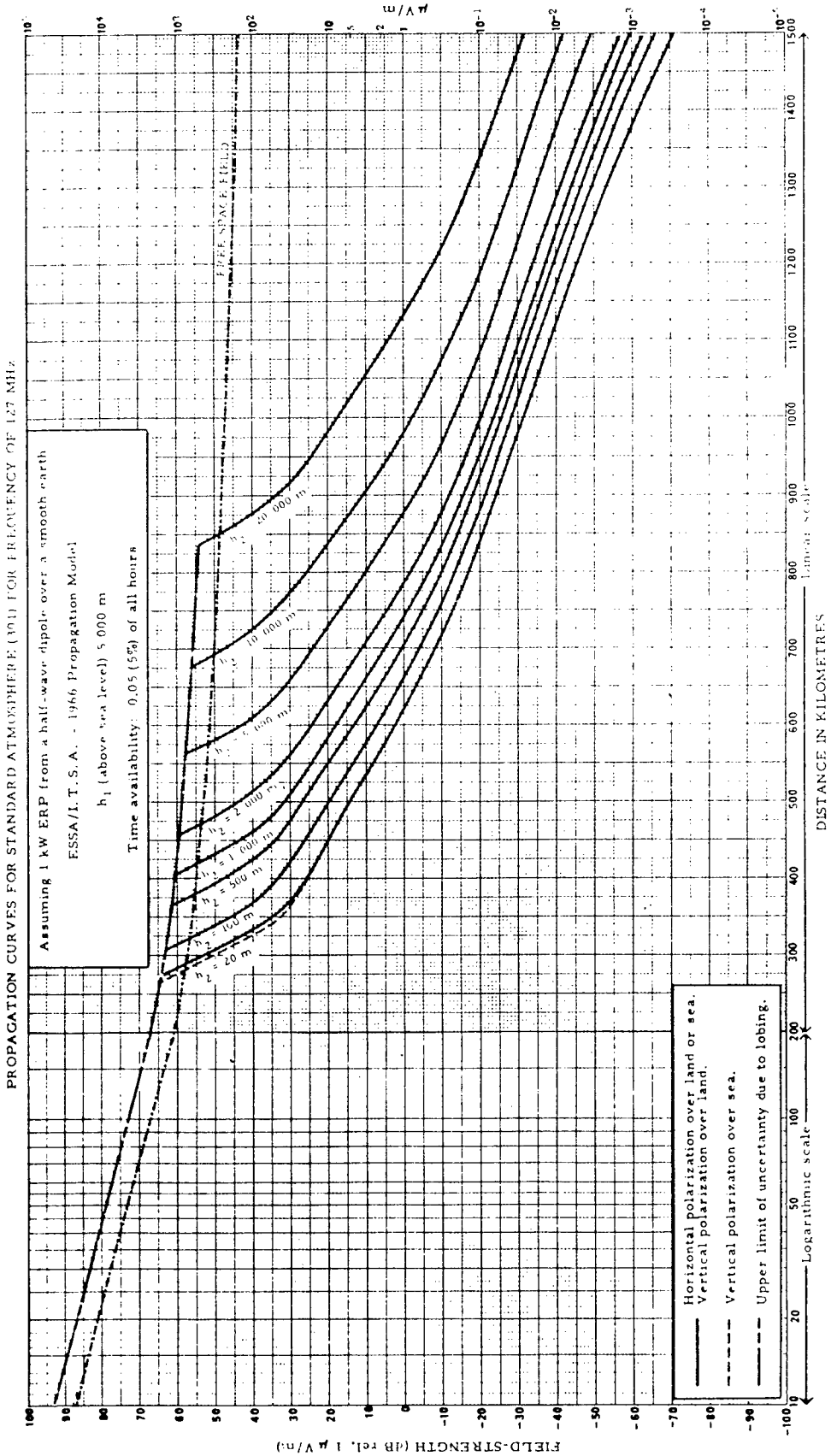

PROPAGATION CURVES FOR STANDARD ATMOSPHERE (301) FOR FREQUENCY OF 127 MHz
Assuming 1 kW ERP from a half-wave dipole over a smooth earth
ESSA/I. T. S. A. - 1966 Propagation Model
h_1 (above sea level) 5 000 m
Time availability: 0.05 (5%) of all hours
FREE SPACE FIELD
h_2 = 20 000 m
h_2 = 10 000 m
h_2 = 5 000 m
h_2 = 2 000 m
h_2 = 1 000 m
h_2 = 500 m
h_2 = 100 m
h_2 = 20 m
Horizontal polarization over land or sea.
Vertical polarization over land.
Vertical polarization over sea.
Upper limit of uncertainty due to lobing.
DISTANCE IN KILOMETRES
Logarithmic scale
Linear scale
FIELD-STRENGTH (dB rel. 1 μV/m)
μV/m

Figure A-12

ATTACHMENT B TO PART II. — CONSIDERATIONS AFFECTING THE DEPLOYMENT OF LF/MF FREQUENCIES AND THE AVOIDANCE OF HARMFUL INTERFERENCE

1. Particularly in areas of high density of NDBs, it is recognized that efficient planning is essential in order to: a) ensure satisfactory operation of ADF equipments, and b) provide the most efficient usage of the limited frequency spectrum available for the NDB service. It is axiomatic that regional meetings will so plan facilities as to ensure that all facilities will receive the best possible protection from harmful interference. Nevertheless, in certain regions, congestion of facilities has been such that regional meetings have had to plan in terms of a *minimum* protection ratio.

Regional meetings include in their planning consideration of such factors as:

a) the possibility of reducing the number of NDBs required, by co-ordination of system plans;

b) the possibility of reducing the coverage where a lesser grade of service than that obtainable within the rated coverage is acceptable;

c) the characteristics of ADF equipments in use;

d) the atmospheric noise grades, appropriate to the area concerned;

e) ground conductivity;

f) interference protection required at the edge of the rated coverage.

Of the foregoing factors, that which is most susceptible to improvement of a technical kind is c).

2. The 1979 World Administrative Radio Conference adopted regulations concerning the assignment of frequencies for aeronautical radio beacons operating in the LF/MF frequency bands. A minimum protection ratio (wanted/unwanted signal ratio) of 15 dB is to be used as the basis for frequency assignment planning (RR 2854). The following data concerning the attenuation characteristics of ADF equipment was used in the EUM region to aid in the frequency assignment process:

Frequency difference (kHz)	*Attenuation (dB)*
0	0
1	1
2	6
2.4	10
3	20
3.6	30
4.3	40
5	50
6	65
7	80

The above figures (or distance separation criteria derived from them) have also been applied in other regions in determining the minimum protection ratio.

Where a bearing accuracy of plus or minus 5 degrees is required at the edge of cover, a minimum protection of 15 dB by day should be used as the basis for LF/MF channel assignment planning.

3. In view of the fact that in many regions there is a need to improve the planning criteria it is considered that the main source from which improvement can be derived is recognition of higher attenuation figures than those given above. Regional meetings are accordingly advised that, when the congestion is such that the use of the above figures no longer permits efficient planning of the LF/MF frequency spectrum available, the following figures represent from a technical point of view the best that can be accepted in determining distance separation criteria:

Frequency difference (kHz)	*Attenuation (dB)*
0	0
1	6
3	35
5	65
6	80

When using these figures, it should be noted that the RF selectivity of modern ADF equipment is in general better than these figures and that, while the RF selectivity of older ADF equipment is not better than these figures, consideration of the dynamic characteristic of these older equipments shows this to be better. It could therefore be expected that frequency planning based on the new figures would considerably improve the service provided to users of modern equipment, and would not materially reduce the service presently provided to those aircraft using the older equipments.

Nevertheless, in their planning, regional meetings would need to consider this question most carefully.

4. It is further noted that, in certain regions, many NDBs are used with voice channels and that this usage is aligned with the Note at the head of Part I, 3.4.6. It is expected that regional meetings will take this fact into account when establishing criteria for frequency planning.

ATTACHMENT C TO PART II. — GUIDING PRINCIPLES FOR LONG DISTANCE OPERATIONAL CONTROL COMMUNICATIONS

Note.— The numerical sequence of the clauses below does not signify any order of relative importance.

1. Aeronautical Operational Control (AOC) HF Stations should be authorized where no other means for the exercise of long distance operational control are available or where the use of the normal communication services provided for safety and regularity of flights are unsuitable or inadequate.

2. The total number of ground stations on the world-wide radio channels should be kept to a minimum consistent with economic and operational efficiency. Consequently,

a) there should normally be not more than one station per State;

b) where an agreed affinity of interest exists between adjoining States, a single station may be provided by agreement among them to serve the needs of all the aircraft operating agencies requiring a service into those States.

3. Depending on the national policy of the State or States, aeronautical stations could be operated by States on behalf of one or more aircraft operating agencies provided that the agencies' requirements for flexibility and direct communication to their aircraft can be met, or aeronautical stations could be operated by an aircraft operating agency or a communication agency serving the interests of one or more aircraft operating agencies and operating under licence issued by the State or States concerned.

4. The licences should be issued on a regular renewal basis and, pursuant to RR 956 and in accordance with RR 3633, should prohibit "public correspondence", or point-to-point type traffic, or other communications traffic not meeting the definition of operational control communications.

5. VHF (general purpose or AOC channels) and not HF should be used when an aircraft is within the coverage of an appropriate VHF aeronautical station.

Note.— The specific categories of messages that may be handled on Aeronautical Mobile (R) Service channels are prescribed in Annex 10, Volume II, Chapter 5, 5.1.8. The same Chapter defines the standard communications procedures for the Service including the requirements for maintaining watch in 5.2.2. In accordance with RR 2025, Article 24 of the ITU Radio Regulations, licences should define the purpose of the station for aeronautical Operational Control (as defined in Annex 6, Part I) and should specify the general characteristics in accordance with Appendix 27 of the Radio Regulations.

— END —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also scribes in general terms the contents of the various ies of technical publications issued by the International Civil Aviation Organization. It does not clude specialized publications that do not fall ecifically within one of the series, such as the ronautical Chart Catalogue *or the* Meteorological bles for International Air Navigation.

nternational Standards and Recommended Prac- es are adopted by the Council in accordance with ticles 54, 37 and 90 of the Convention on ernational Civil Aviation and are designated, for nvenience, as Annexes to the Convention. The iform application by Contracting States of the cifications contained in the International Stan- ds is recognized as necessary for the safety or ularity of international air navigation while the iform application of the specifications in the commended Practices is regarded as desirable in interest of safety, regularity or efficiency of ernational air navigation. Knowledge of any differ- es between the national regulations or practices of State and those established by an International ndard is essential to the safety or regularity of ernational air navigation. In the event of non- npliance with an International Standard, a State , in fact, an obligation, under Article 38 of the nvention, to notify the Council of any differences. owledge of differences from Recommended Prac- es may also be important for the safety of air igation and, although the Convention does not pose any obligation with regard thereto, the uncil has invited Contracting States to notify such ferences in addition to those relating to Internanal Standards.

rocedures for Air Navigation Services (PANS) are proved by the Council for world-wide application. ey contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of region navigation meetings and of the Council actio on. The plans are amended periodically to reflec changes in requirements and in the status of impl mentation of the recommended facilities and servi

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